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DRAFT

WORKING PAPER

METHOD, MYTH AND MODEL: ANALYSIS AND THE INTERNATIONAL TRANSFER OF TECHNOLOGY

by

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"I am fast bound, I must endure.
I gave to mortals gifts.
. . . .
These are the crimes that I must pay for
pinned to a rock beneath the open sky."

Aeschylus, Prometheus Bound

"When they bury us in the ground alive . . .
please do not send them shovels."

Aleksandr Solzhenitsyn

PREFACE

This study is a contribution to a larger program sponsored by the Defense Advanced Research Projects Agency which has the following objectives:

1. The development of methods for evaluating how the Soviet Union uses technology.
2. Comparing and contrasting the Soviet Union's processes for using technology with that of other countries, especially the United States.
3. The identification of indicators of the status of Soviet economic and technical development and the assessment of changes in these variables over time.

The objective of the present work is to determine the value of the existing literature on the international transfer of technology for the accomplishment of the program's overall objectives.

In order to achieve this goal and also produce a document that can provide a thorough, but concise introduction to the research on the subject, a preference has been shown for the retention of other authors' explanations when appropriate. I have relied on the selection and juxtaposition of this material to make particular points.

The title gives the theme of the work, namely, that both the belief in and the neglect of certain "myths" have prevented and, in some instances, substituted for improvements in the analysis of U.S. policies concerning technology and international relations.

The reader who is already conversant with the literature may find it expedient to selectively omit the more detailed descriptions of the methods of analysis and concentrate, instead, on the synopsis provided in the summary.

While I have drawn from many sources, the conclusions and recommendations are my own.

ACKNOWLEDGEMENTS

I am especially thankful and indebted to the following individuals for the assistance they provided in directing me to appropriate sources of information:

Professor Albert H. Rubenstein, Northwestern University; Professor Edwin Mansfield, University of Pennsylvania; Rolf R. Piekarz, National Science Foundation; Dr. Herbert A. Levine, University of Pennsylvania; Dr. John Hardt, Library of Congress; Professor Henry Nau and Gordon K. Gayer, George Washington University; Mr. Edward Grey, NASA; Dr. Bruce Robinson, Department of Commerce; Dr. Daniel Spencer, Morgan State University; and Dr. Thomas J. Allen, MIT.

While the usual disclaimers regarding their responsibility for my work apply, their efforts eased my difficulties in locating many of the references on which this report is based.

SUMMARY

I. INTRODUCTION

The issues confronting decisionmakers in their attempts to use the development and transfer of technology as an instrument of U.S. national security policy can be partitioned into four generic types:

1. The international transfer of technology as a variable in East-West relations.
2. The comparative advantage of the U.S., relative to the Soviet Union, in the use of technology.
3. The effect of international technology transfers on the economic position of the U.S.
4. The nature of U.S. technical assistance to new and industrializing nations.

Very little attention, however, has been given to the analytical foundations which provide the basis for policy decisions in these areas, especially as they pertain to our relationship with the Soviet Union, since the belief in certain 'political myths' (e.g. "Trade with the Communists is bad." "Trade with the Communists is good." "The U.S. must maintain leadership in all areas of technology.") has, until recently, substituted for more traditional kinds of analysis.

More refined definition of the issues and their subsequent decomposition into researchable questions is necessary. This stage is especially critical, since a clear statement of purpose is an essential step in implementing a case survey method, the most desirable approach to answering questions about the international transfer of technology, given the current state of the art.

II. A CAUTIONARY NOTE ON LANGUAGE

The relatively underdeveloped nature of this field of inquiry implies that discussions of the international transfer of technology are apt to be found wanting in clarity. In order to alleviate some of the linguistic difficulties in the subsequent presentations, the reader may find it convenient to think of 'technology', when not defined more specifically, as the organization of knowledge for the achievement of practical purposes.

Similarly, in spite of the numerous properties ascribed to technology, the reader should not make the mistake of regarding expressions like the 'absorption' of technology as concepts rather than mere words, since, with few exceptions, their users have not been forthcoming in presenting explications of these terms.

One need not believe that the achievement of a uniform vocabulary is indispensable for progress in research (the "semantic myth") in order to recognize that these linguistic problems have impeded the development of the field.

III. THE BARE ESSENTIALS

If one assumes that technology is knowledge of a special kind, then, independent of the particular policy question of interest and associated with the theoretical descriptions of the technology transfer process, the simplest general representation of the phenomenon is an analogical model deducible either from information theory or the classical model of the diffusion of innovations. This model posits the existence of a donor and recipient connected by a channel via which technology is presumed to pass. "Typical" (non-inclusive, overlapping) lists of channels usually contain the following entries:

1. Personal contacts
2. Immigration
3. Technical publications
4. Exhibitions
5. Licensing
6. Patents
7. Reverse engineering of products
8. Joint ventures.

(Consult the text for additional examples.)

The enumeration of the various channels and hypotheses regarding their comparative efficiencies is, relative to the size of the field, a small industry in its own right. On the other hand, studies of the relative costs and benefits to the respective participants, as a function of the channels employed, are conspicuous by their absence, in spite of numerous recommendations that this research be undertaken. Furthermore, it is not clear to what extent some channels are substitutes for or complements and composites of others. As a result, there is likely to be a highly contentious "distributional" problem associated with the construction of preference rankings over these lists, even for particular cases, let alone in the abstract.

IV. VARIATIONS ON A THEME

Refinements of the simple donor-recipient model of the technology transfer process take three forms:

1. Construction of a typology of transfer processes.
2. Introduction of intermediate stages or participants between the donor and the recipient.
3. Disaggregation of the organizational and decision-making structures implied by the words 'donor' and 'recipient'.

Advances in the explanatory power of hypotheses about the transfer process have not, unfortunately, kept pace with the quest for descriptive validity represented by these variations.

V. THE MYTH AND THE METHODS

Several methods of analysis have either been applied or are thought to be of value as an aid in answering questions about the international transfer of technology. These include:

1. Case Survey Methods
2. Propositional Inventories
3. International Technological Gatekeepers
4. Economic Analysis of Diffusion
5. Substitution Analysis
6. Spatial Analysis of Diffusion of Innovations
7. Multiple Criteria Decisionmaking
8. Edgeworth-Bowley Box Diagram
9. Utility Theory
10. International Trade Theory
11. Technology Transfer Functions
12. Technology Transfer Index

This review has concentrated on the following points in the synopsis of each method:

1. What is the question or policy area to which the method is addressed?
2. Are there instances of empirical validation of the method?
3. How "macro" or "micro" is its focus? What are the units of analysis involved?
4. What are the likely difficulties in applying this method?
5. What are the implications for the larger program?

The results of the survey are presented in the accompanying table. The reader should not, however, succumb to the "myth of methodology," the deceptively alluring notion that if only one had the "right" method, one's questions could be answered.

In light of the state of the art in this field, a case study approach is the preferred method of analysis. What is needed is a procedure for bringing the results of case studies together under a common conceptual framework so that findings can be cumulative. The case survey method is one such aggregation technique. While it is still in its formative stages of development, the results of the few applications to date warrant the investment of additional resources in the pursuit of similar research. Furthermore, when compared with the other analytical techniques that are currently available, the case survey method is clearly the most promising approach to be developed within the context of the larger program. The objective of such an application should be the accumulation of an inventory of propositions, accompanied by evidence for their support or refutation, which address themselves to the research questions associated with the policy area of interest. All of the remaining methods of analysis to be discussed could then be applied within this framework when appropriate to the question under consideration.

If, from the perspective of the simple donor-recipient model, technology transfer is regarded as a "people process", we might ask whether some people are more important than others in functioning as a transfer channel. The literature on communications theory argues that, indeed, there is one type of individual worth examining in some detail, the international technological gatekeeper. The function of the gatekeeper

SYNOPSIS OF EXISTING METHODS OF ANALYSIS

Method of Analysis	Heuristic Motivation	Empirical Validation	Unit of Analysis	Problems in Applying	Implications for Larger Program
Case Survey	Aggregation of case experience	Limited		Generation of checklist	Preferred overall method
Propositional Inventory	Theoretical development of field	Limited		Operational Definition of Variables	Case survey checklist, questions of interest
International Technological Gatekeeper	Efficiency of R&D Communication Process	Limited	Individual	Data availability	Identify Soviet gatekeepers
Economic Analysis of Diffusion	Explain diffusion in economic variables	Extensive	Firm	Data availability	Comparative study of innovation diffusion
Substitution Analysis	Diffusion as competition between alternatives	Extensive	Firm	Data availability	"
Spatial Analysis of Diffusion	Explain diffusion in cultural, geographic terms	Limited	Individual	Data availability	"
Multiple Criteria Decision Making	Explain technologically new products in theory of the firm	None	Firm		Complementary nature of technology transferred Technology base
Edgeworth-Bowley Box Diagram	Welfare economics, impact of technology transfer	Limited	Nation		Fungibility of Soviet resources
Utility theory	Export Controls	None	Nation	Multi-attributed utilities	Source of questions on export controls
International Trade theory	Technology gap, product cycle school	Limited	Nation	Data availability	Comparative study of response efficiencies
Technology Transfer Functions	Macroeconomic impact of technology transfer	Limited	Nation	Data availability	
Technology Transfer Index	Nonmonetary measure of technology transferred		Firm		Subjective assessment of technical diffusion, substitution, new products

is to serve as an internal consultant to the average member of an organization on external sources of information. While it has been possible to identify the existence of technological gatekeepers, their specific contributions to the success or failure of particular projects have not been examined. This extension should be made, especially in the case of Soviet R&D activities in both the military and civil sectors of the economy.

If, on the other hand, the transfer of technology is assumed to be a special case of the diffusion of innovations, it is possible to identify three distinct but complementary research traditions: the social-psychological, the economic and the geographic. Each of these traditions differs in the emphasis it places on the various factors which affect the adoption of innovations and their rate of diffusion.

Explanations of the roles of gatekeepers, product champions, change agents and opinion leaders in securing the adoption of innovations by the organizations of which they are a part are in the first category.

The leading explanation of the diffusion of technical innovations from firm to firm in a market economy in terms of economic variables is based on the following four hypotheses:

1. As the number of firms in an industry adopting an innovation increases, the probability of its adoption by a nonuser increases.
2. The expected profitability of an innovation is directly related to the probability of its adoption.
3. For equally profitable innovations, the probability of adoption is smaller for innovations requiring relatively large investments.
4. The probability of adoption of an innovation is dependent on the industry in which the innovation is introduced.

While tests of the theory lend support to the preceding hypotheses, it has been criticized for not including the extent of the firm's dependence on the innovation and detailed representations of the internal decisionmaking structure. Existing research on the importance of these factors, however, leaves the matter unresolved.

Another refinement of the preceding analysis adopts the view of the competitive substitution of one product, service, or process for another.

A typical model of this process of competitive substitution is based on the following assumptions:

1. Many technological advances can be considered as competitive substitutions of one method of satisfying a want for another.
2. If a substitution has progressed as far as a few percent, it will proceed to completion.
3. The fractional rate of substitution of new for old is proportional to the remaining amount of the old left to be substituted.

While substitution plots do not reveal the underlying causes for international differences in the acquisition and use of technology, they do, nonetheless, provide a means to identify trends and to suggest propositions that merit further study.

The explanation of the diffusion of innovations in geographical terms has its roots in cultural anthropology. The assumption is made that successful innovations tend to cluster in space and time. The spread of these innovations in society, furthermore, exhibits certain regularities beginning with the adoption of the innovation by a concentrated cluster and expanding in such a way that the probability of new adoptions is higher among those nearer the earlier adopters than those who are farther away. It is also assumed that the geographic structure of the network of social contacts associated with the diffusion of innovations changes very slowly and, hence, is predictable. While other versions include hypotheses concerning unevenly distributed "receptiveness" and "resistance" to the innovation in question, empirical tests of the propositions have not been carried to the point where the prognostic value of this approach can be ascertained.

The relationship of this work to the earlier discussion of the economic explanation of diffusion patterns based on profitability differentials is clearer if, for investment decisions, profitability measures are included in an index of "resistance to" or "readiness to assimilate" the innovation.

Multiple criteria decisionmaking attempts to expand the theory of the firm to include an explanation of how technologically new products come into being by assuming that technological change is a process by which a vector of physical characteristics associated with a product is optimized. Because of its similarity to the known "ripple effect" caused by technical innovations, empirical validation of the formulation in the context of explaining the complementary nature of technology transferred or the growth of a nation's technology base is in order.

The issue of the "fungibility" of the resources released by the transfer of technology to the Soviet Union lends itself to formulation in terms of an Edgeworth-Bowley box diagram. However, its application is likely to suggest general policy implications and hypotheses for research, rather than answers to specific questions of a more detailed nature.

Much the same can be said for the attempt to apply utility theory to the question of export controls. These methods of analysis are, nonetheless, valuable tools in providing a formal structure to the policy issues associated with the transfer of technology to the Soviet Union.

Explanations of trade patterns in terms of the comparative advantage obtained by lags in the adoption of innovations by different countries have, quite naturally, concentrated on the changes in the economic positions of the trading nations. In light of the empirical testing of this theory, however, its application to the military arena and especially to an examination of the effect of technical innovation on U.S.-Soviet arms competition should be ventured.

An alternative to the treatment of technology as a residual factor in a production function format is provided by a set of estimating relationships called transfer of technology functions. These functions are of two types: impact functions and absorption functions. The first attempts to relate significant variables determining the output of goods related to the new technology that was borrowed from abroad. The second set is concerned with what variables facilitate a society's ability to absorb technology. Although existing regression equations are available for a collection of macroeconomic variables and have been applied to the post-war reconstruction of West Germany and Japan, the immediate relevance of this approach to the larger program of study is unclear.

The technology transfer index is an attempt to use a multidimensional scaling technique to subjectively assess the amount of technology transferred in nonmenetary terms. Success in actually applying the index has yet to be reported, however, and the approach is still in its early stages of development.

In the near term, existing methods of analysis would appear to be applicable to questions involving the effect of various government policies on either speeding up or delaying the international spread of particular technologies, subject, of course, to constraints on data availability.

VI. A SYNTHESIS OF EXISTING METHODS

Of more immediate concern, however, given the program's overall objectives and expert opinion on these questions, is the development of a systematic procedure for examining the relationship between organizational structure and the acquisition and adoption of technical innovations. The only promising method for doing so is based on a synthesis of case study aggregation techniques, abstract descriptions of the technology transfer process and models of organizational processes and bureaucratic politics. Although the development of this approach will result in an inventory of propositions on technology transfer issues to which policymakers can turn for assistance in answering their questions, the changing nature of the Soviet Union's organizational structure under conditions of economic reform means that any inventory of propositions will need to be periodically reviewed and updated with follow-on cases. This will, of course, be true of any method which focuses on organizational structure as an explanatory variable in the technology transfer process. The method just described, however, has the benefit of demonstrated feasibility and a backlog of propositions, analytical frameworks and case studies on which to build.

VII. CONCLUSIONS

The state of the art in the analysis of the international transfer of technology is such that this field of study is not of direct and immediate assistance in answering policymakers' questions. The literature is, nevertheless, a valuable source of guidance on the design of methods of analysis which offer a greater chance of success in accomplishing the objectives set out in the preface to this report than might otherwise be the case.

Given the current state of the art, a case study approach is the preferred method analysis. In particular, in order to take advantage of existing research and increase its relevance for policymakers, a comparative study of the development and diffusion of technical innovations in the U.S. and Soviet Union, which has as its objectives the development of a propositional inventory and the validation of a method of analysis based on a synthesis of organizational process models, abstract descriptions of the technology transfer process and case survey techniques, should be undertaken.

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I. INTRODUCTION*

The recognition of the value of technology as a "bargaining chip" for U.S. diplomacy and an instrument of U.S. national security policy continues to grow.[1] The transfer of technology from West to East (and, sometimes, vice versa) is an integral part of a policy of "peace through linkage".[2]

At the same time, the preeminence of U.S. technological superiority over the Soviet Union in the military sector is the basis of a U.S. strategy which hedges against the uncertainties of the future and the vagaries of political opinion, both at home and elsewhere.[3]

Technology has even come to take on increased prominence in our international economic relations, whether as a component of our trading policies with other developed countries, or as part of our foreign aid programs with developing nations.[4,5]

This increase in the interest of U.S. decisionmakers with the use of technology as an instrument of policy has been accompanied by a corresponding concern that the analytical foundations which provide the basis for such decisions are not as sturdy as they might be, especially as they pertain to our relationship with the Communist nations, in general, and the Soviet Union, in particular.

Traditionally, the outcomes of deliberations on the advantages and disadvantages of trading with the Communists have hinged on the strengths of the decisionmakers' beliefs in certain political myths:

> If prior to the early seventies the dominant belief was that trade with Communists isn't trade, it's bad, a prevailing supposition now is that, while still not just trade, it's good. Thus over the past quarter-century we have gone through several phases with respect to our views of business with Communists.
>
> Phase 1(High cold war): As soon as a transaction would procure economic gain to Communists-and which would not (after all, it's a transaction)?-one should abstain from it.
>
> Phase 2(Low cold war): If our economic gain would exceed theirs, we may engage in a transaction with them.
>
> Phase 3(Low detente): Never mind how small our economic gain and how large theirs; as soon as there is political gain from a transaction, it should be undertaken.

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*Footnotes have been accumulated at the end of each section. Detailed references to sources cited appear in the bibliography at the end of the report.

Phase 4(High detente): Never mind how large (up to a limit left undetermined) our economic loss and how large their economic gain; as soon as there is political gain from a transaction-or avoidance of political loss, which might be substantial-it should be undertaken.

Phase 5(Normalcy achieved): Never mind our or their political gain, or their economic gain; as soon as there is economic gain for us we should do it. And the greater their economic gain, the greater the future political gain for us.

As to the impact that economic relations with us might have on the Soviets' potential for creating military power, it used to be argued by those who proposed to abolish the barriers erected around 1950 against transactions with Communist states that a sufficient safeguard was to limit our exports to "non-strategic" items. However, slowly the point of economics about the "fungibility" of factors of production through time has left its mark: any exchange-and particularly one involving high-technology Western goods or "disembodied" high Western technology-would leave the Communist states with resources changed in such a way that a given increment of military goods could subsequently be produced with a smaller loss to the non-military sector.[6]

Now, however, even the definition of the issues is apparently a point of contention.[7] Moreover, as the Soviet Union continues to increase its investment in military research and development, a U.S. strategy which strives for technical leadership in all areas becomes less preferable to one based on an extension of the principle of comparative advantage.

(The) principle of comparative advantage (can be put) in terms of the language of power as the principle that, no matter whether a country is absolutely strong or absolutely weak, it can maximize the power available to it by concentrating on those activities in which it is relatively more powerful and hiring the services of specialists in those activities in which it is relatively weaker.[8]

(It) has become essential to assess the military-technical balance as perceptively as we possibly can and in great detail, for we may not be able to afford to compete with the Soviets where they are strong. We need to know our comparative strengths and their comparative weaknesses and exploit them. We need to know where our initiatives will pay off best. We can -- and we must-- stay ahead in fields that are important for maintaining a military balance on our teams.[9]

What are the comparative costs of being a leader or a follower in specific technology areas? Where can we most effectively trail? Can we save money by doing so? Where should we try to stay ahead? Where should we be trying to build new areas of comparative advantage through R&D?[10]

In short, the model that we should adopt is one of a competitive adaptation through the introduction of new technologies which meet our needs, not through an attempt to form a cartel with adversaries in restraint of technology.[11]

The objective of this paper is to determine what contributions the existing literature on the international transfer of technology can make to a larger effort which aims at strengthening existing analytical approaches and assisting U.S. decisionmakers accordingly. In light of expert evaluations of the state of the art in this field, the prospects are less than promising for readily accomplishing either task based solely on past research.[12]

Linguistic aspects of the analysis of the properties of technology and the state of the development of their associated operational definitions are treated in section II.

The simplest general model of the technology transfer process is presented in section III, including enumeration of alternative transfer mechanisms and hypotheses relating the elements of this simple model.

Refinements of this model are discussed in section IV.

Section V reviews some existing methods of analysis that have either been applied or are thought to be of value as an aid in answering questions about the transfer of technology.

In light of the relationship between organizational structure and the development and adoption of technical innovations, section VI presents a synthesis of case study aggregation techniques, abstract descriptions of the technology transfer process and models of organizational processes and bureaucratic politics.

Section VII concludes with some observations and recommedations for additional research.

Appendices A,B, and C contain expert opinion on, respectively, the state of the art, "preferred" methods of analysis, and the "conventional wisdom" about the technology transfer process.

NOTES

1. The most recent general introduction to the problem is Kinter and Sicherman (1975).

2. For elaboration see:

   Kissinger (1974, p. 8), Kalb and Kalb (1975, pp. 125, 141, 376, 497, 499), Wohlstetter (1974, pp. 1112-1115), Nutter(1975, pp. 19-20, 23),

   Leites (1973), Campbell and Marer (1974), Wolf (1974), Dehaven (1974), Spivak (1975, p. 32), U.S. House of Representative (1973), Simmons (1974), Shulman (1973), Leonhard (1973), Nove (1973), U.S. Senate (1974), Petrov (1975), American Academy of Political and Social Science (1974), Foster (1974), Branscomb (1975), Nau (1975), U.S. Senate (1972), Hardt and Holliday (1973), Sutton (1973), Grayson (1974), Hanson ( ), Inozemstev (1975), Patolichev (1975), Jackson (1974), Hotz (1974), Schemmer (1973, 1974).

   Relevant background information on the Soviet Union is contained in the following: Harvey, et. al. (1972), Lewin (1974) U.S. Joint Economic Committee (1974), U.S. Joint Economic Committee (1973), U.S. Joint Economic Committee (1970), Nolting (1973), Zaleski et al. (1969), Davies and Amann (1969), Amann (1972), Gvishiani (1971), Nove (1968), Gregory and Stuart (1974), Grayson (1972), Grossman (1966), Campbell (1972), Berliner (1973), Schroeder (1970), Granick (1973, 1975), Landis (1975), Ulsamer (1975), Steele (1974), Schemmer (1974).

   Eastern European concerns are discussed in: Wilczynski (1974, 1975), Zoubek (1975), Marks (1969), Hewett (1975), Osers (1972), and Gallagher (1974).

3. Schlesinger (1966), U.S. House Appropriations (1976, pp. 531-2, 547-8, 575-77), Marshall (1972), Currie (1974, 1975) Brown (1975), Canby (1975) Leites (1973, p. 32; 1950, pp. 88-90), Pillsbury (1975).

4. CIEP (1974, 1975), NSF (1974), U.S. Department of Commerce (1970), Mansfield (1974), U.S. Bureau of Labor Statistics (1974), David (1974), NAE (1970, 1975), Gee (1975), deBrichambaut (1974), Nelson (1968), Eads (1974).

5. The role of technology in transforming Japan is discussed in Fischer (1974), Kleiman (1974), Ozawa (1972, 1974), Oshima (1974), JES (1973), Long (1975), Uchino (1973), CIEP (1971b, pp. 57-73).

   The value of technical assistance to developing countries is discussed in OECD (1974), Hawthorne (1971), OECD (1972), Cooper (1973), Shand (1973), Hansen (1970).

NOTES (contd)

For the relationship between international technology transfer, economic nationalism, raw materials and U.S. foreign aid policies see Oelsner (1975), Connelly & Perlman (1975, p. 134), Johnson (1965, 1966, 1967), Sutulov (1974), Kilmarx (1975), Pontecorvo (1974), Varon and Takeuchi (1974), Kay (1974).

The problem of the proliferation of nuclear technology is treated in Zoppo (1971).

6. Leites (1973, p. v). A political myth is any statement about political affairs which, whether in fact it is true or false, is believed to be true with such confidence that is no longer bears the character of an assumption. For elaboration consult Lasswell and Leites (1949, pp. 9-10).

7. Campbell and Marer (1974, p. 3).

Commenting on U.S. export control practices, Klitgaard (1974, pp. 80-81) argues:

> (It) must be remembered that at present only two basic questions are considered during list reviews: Does the good have a military use in the United States? Does it contain technology not possessed by the Communist countries? If the answer to both is 'yes', the good is restricted. Furthermore, all strictly military goods are automatically restricted.

His suggested questions for consideration during list reviews and exception requests are included in Appendix B.

8. Johnson (1975, p. 1).

9. Currie (1975, pp. II- 2,3).

10. Marshall (1972, p. viii).

11. Rowen (1975, p. S12293). Also see Wohlstetter (1974, pp. 1143-4).

12. See Appendix A for expert evaluations of the state of the art. More detailed treatments can be found in Ray (1975), Uhlmann (1975), National Science Foundation (1974), Cetron (1974), Kohler et al. (1975), Chakrabarti (1972,1973), Mansfield (1975), Rubenstein (1972, 1974), Douds (1971, 1974). The specific research needs in the case of East-West technology transfer are reviewed in Campbell and Marer (1974).

II. A CAUTIONARY NOTE ON LANGUAGE

Leonard Bloomfield has argued that:

> The use of language in science is specialized and peculiar. In a brief speech the scientist manages to say things which in ordinary language would require a vast amount of talk. His hearers respond with great accuracy and uniformity. . . .Along with systematic observation, it is this peculiar use of language which distinguishes science from non-scientific behavior.[1]

Indeed, it would appear that, with some notable exceptions, discussions of the international transfer of technology are aptly characterized by their peculiarity rather than their clarity. The following points are intended to alleviate some of the linguistic difficulties in the subsequent presentation of the substance of existing analyses.

The reader may find it convenient to think of 'technology', when not defined more specifically, "as tools, in a general sense, including machines, but also including such intellectual tools as computer languages and contemporary analytic and mathematical techniques".[2] How it differs from 'knowledge','know-how 'skills', etc., is not clear.[3]

The properties of technology are such that, according to those presumably in the know, it can be 'absorbed', 'acquired', 'assessed', 'assimilated', 'borrowed', 'developed to varying degrees', 'diffused', 'exchanged', 'exported', 'implemented', 'imported', 'introduced', 'pulled', 'pushed', 'shared', 'spread', 'transferred', and 'utilized'. The reader should not make the mistake of regarding this "overwhelming heap of termini technici" as concepts rather than mere words, since, among other things, their users have not been forthcoming in presenting explications of these terms.[4] This is not surprising in light of the current state of the art.[5]

> Discussion of definitions, the purpose of which is to delimit a field of inquiry through specifying its distinctive and constituent characteristics, can lead to no more than judgments whose relevance can be tested only by the development of research in the field. Likewise, discussion of problems of measurement can, unless much quantitative work in the field has already been done, lead only to suggestions that still have to stand the test of prolonged experimentation with the linkages between the available data and the desired quantitative counterparts of analytically defined concepts. The field under consideration has not reached the state of development in which canons of definition and measurement can be derived as conclusions distilled from already accumulated experience.[6]

What little "terminological empiricism" there is in this field leaves the question of operational definitions unresolved.

There was no agreement on what words to use or on whether it matters what words are used. Some participants felt that discussion of terminology was a waste of time, because one could separate the real issues from the terminology. Others argued that terminology is not neutral and may frequently influence our thinking and action.[7]

NOTES

1. Bloomfield (1939, p. 1).
2. Mesthene (1970, p. 25). Alternatively, one can distinguish between material technology and social technology. See Kuznets (1975, vol. II, p. 476).
3. See Spencer (1967-1968, p. 15) for a discussion of technical knowledge and know-how.
4. Hempel (1952, pp. 11-14); Neurath (1944, p. 3). An exception is Ruttan's (1959) discussion of the concepts invention, innovation and technical change in Usher's cumulative synthesis theory of strategic inventions as contrasted with their use in Schumpeter's explanation of the process of economic development.
5. See Appendix A.
6. Simon Kuznets, "Inventive Activity: Problems of Definition and Measurement" in National Bureau of Economic Research (1962, pp. 42-43).
7. OECD (1974, pp. 13, 21-30). See Kaplan (1964, pp. 71, 289) for a discussion of the semantic myth as an alleged impediment to the development of methodology in the behavioral sciences.

III. THE BARE ESSENTIALS

If one assumes that technology is knowledge of a special kind, then the simplest general model of technology transfer posits the existence of a donor and a recipient connected by, to borrow from the language of information theory, a channel or collection of channels.[1]

Rottenberg develops this perspective in the following manner:

> Knowledge does not move from place to place at zero cost. Real resources must be devoted to both its transmission and its reception. The quantity that will move can be expected to be an inverse function of the unit cost of movement. Whatever diminishes the quantity of resources employed in transferring a unit of knowledge will cause the number of units transferred to be larger. The quantity moved will also be a direct function of the total cost of the movement. The larger the total quantity of resources devoted to the spatial transfer of knowledge, the larger will be the magnitude of movement.
>
> A number of observations about the processes of the transfer of knowledge are suggested by analogy from information theory. Imagine signals being emitted by a source, passing through channels, which are media over which signals are transmitted, and being received. The signals may be more or less powerful when emitted; their number may be more or less numerous in some time period; they may be repeated with more or less frequency. The channels through which they move may be more or less "noisy" (there may be more or less resistance to the transmission); they may be narrow or wide; the noise may be equally distributed in the channel or some parts may be relatively noise-free. The number of channels may be many or few; given signals may be transmitted over only one or more than one channel. There may or may not be filters separating signals from signals-cum-noise; if there are filters, they may be more or less efficient.
>
> The movement of knowledge simulates the processes postulated by information theory. The relevant variables determining the volume of flow of knowledge from places with large stocks to those with small stocks seem to be the following:
>
> 1) the quantity of knowledge emitted at the source;
>
> 2) the quantity of resources employed in emission;
>
> 3) the frequency of repetitive emission of any given unit of knowledge;

4) the number of channels over which transmission occurs;

5) the dimensions of these channels;

6) the degree of freedom with which emitted knowledge flows through channels; and

7) the quantity of resources employed in reception.

These hypotheses are, however, not helpful until we are able to achieve pragmatic verification of the variables. The "quantity of knowledg e" is an empty phrase until units of knowledge can be assigned their appropriate weights. Populations of weights will be variant from place to place; their structures will depend upon the kinds and quantities of resources which knowledge complements in different places.

It is uncertain whether the cost of retransmission falls or rises at the margin, or whether it is constant. Nor is there a certain rate at which knowledge received increases as the number of repetitive transmissions increases; nor again is there a fixed relationship between the rate of increase of received knowledge and diminished durations of intervals between transmissions of a given unit knowledge. Unless these marginal cost and marginal "revenue" schedules can be at least implicitly constructed, one cannot know the optimal number and frequency of retransmissions.

What is the meaning of "dimensions" of a channel used for conveying knowledge? The breadth of a channel may be said to be determined by the efficiency with which it carries knowledge from place to place. If we assume a given quantity of resources devoted to emission, transmission, and reception, that channel is broadest which causes the smallest numerical ratio of the quantity of knowledge emitted to the quantity of knowledge received. Channels of communication are myriad. Some that are broad in one cultural context are narrow in another. We cannot yet distinguish clearly the large and small dimension channels in given cases. We do not yet know the principles for the optimal asscciation of characteristics of channels and the characteristics of culture; nor do we even know which cultural characteristics are relevant and which irrelevant to the construction of this association. Of those that are relevant (were we able to make the foregoing distinction), we do not know which are to be heavily weighted and which only lightly.

Similarly "noise" in channels is culturally determined. Noise, in information theory, is whatever causes information received to be different from information emitted. There are such noises in channels over which knowledge is transmitted. In addition, there are "noises" of another kind - those that impede the free flow of knowledge, causing the flow to be viscous and increasing the cost of moving a given quantity of knowledge over a given distance in a given time. Both kinds of "noise" are variant with cultures. The qualities that produce differences of some magnitude between emitted and received knowledge among Basutos are not the same as those producing this difference among Canadians; similarly, the qualities that raise the cost of transmission for the one are not the same as those that do so for the other. We know little about what the respective qualities are.

Resources employed in the reception of knowl dge may be of high or low quality. The higher the quality, the less the quantity of resources needed to bring off a given transfer of knowledge. We can distinguish these qualities of different resources ex post by examining the cost of some output transferred in different ways. But we do not seem to know how to rank resources qualitatively by some technique that is independent of output.

The burden of the foregoing paragraphs is that the principles of optimization for the knowledge-transferring industry can be spelled out; what is difficult is to apply them.[2]

While several researchers have compiled lists of the various transfer mechanisms, (see Tables 1-5 and Figure 1), there have been very few evaluations of the relative costs and benefits of using one combination of channels versus another, even though schemes for doing so (see Figure 2 and 3) abound.[3]

Table 1 : A LIST OF TRANSFER CHANNELS

1. Multinational corporations, internal personnel transfer or the acquisition of a foreign subsidiary.
2. Foreign student exchange program.
3. Foreign aid programs (economic).
4. Foreign aid programs (military).
5. Selling end items (with maintenance manuals, blueprints, etc.).
6. Industrial shows, exhibits and trade fairs.
7. Selling components (avionics packages, propulsion plants, etc.).
8. Technical meetings.
9. Patents.
10. Open literature.
11. Production licensing.
12. Immigration/emigration (the brain drain and reverse).
13. Technical literature

Source: Cetron (1974, P. 7)

Table 2: THE CHANNELS OF TRANSFER

1. Simple licensing
2. Information sharing agreements between governmental departments or institutions and enterprises
   a. Systematic information exchanges on research programs and results
   b. Exchanges of industrial exhibitions
   c. Exchange visits of scientists and industrials
3. "Turn-key" plant
4. Coproduction agreements
5. Joint ventures
6. Joint research and development
7. Personal contacts

Source: Adapted from Economic Commission for Europe (1973, pp. 111-113)

Table 3 :

MEDIA OF TECHNOLOGY TRANSFER

Printed Materials

- Documentation
  - Collection
  - Cataloging
  - Storage
  - Retrieval
- Publication
  - Professional Journals
  - Trade Publications
  - Vendors Catalogs
  - Operating Instructions
  - Textbooks
  - Government Publications
  - Printed Mass Media
  - Clipping Services

Electronic Mass Media

- Radio
- Television

Graphical Materials

- Films
  - Slides
  - Strips
  - Movies
  - Sound and Silent
- Other
  - Charts
  - Bulletin Boards
  - Models
  - Displays, etc.

Products

- Finished
- Intermediate
  - Unfinished Goods and Inpu
  - Equipment
    - Latest-modern
    - Average-state-of-the-ar
    - Old-but-up-dated
    - Old-but-still-in-use
    - Old-and-forgotten
    - Scaled-down-modern

People

- Friends
- Salesmen and Customers
- Consultants
- Expatriates

Source: Hansen (1970, p. 198)

FIGURE-1. MODELS OF ENTERPRISE RELATIONSHIPS IN EAST-WEST TECHNOLOGY TRANSFER

	One-Shot	Long-Term		
Definition:	Sale of equipment, license and/or plant for cash or unrelated products	Provision of technical assistance and/or trademarks for cash and/or purchase of resultant products		
Duration:	Termination upon completion	Usually 5-15 years		
Content:	Contract for design, manufacture and delivery of equipment	Model A Technical Assistance (T.A.) only	Model B T.A. + trademark rights	Model C T.A. + trademark rights + resultant product purchase
Examples:	Swindell-Dressler and the Kama River Truck Plant in the Soviet Union	General Tire in Romania	Honeywell in Poland	International Harvester and Singer in Poland

RELATIONSHIP

DEEPENING INDUSTRIAL CO-OPERATION

Source : Hayden and Nau (1975, p. 3)

TABLE 4: TYPOLOGY OF PROPAGATION MECHANISMS

Type of Linkage / Level of aggregation	Observable Artifact to Adopter	Person/Organization to Adopter	Media to Adopter
International	World Fairs, Shows Exhibitions	International Organizations (e.g., WHO) Private Sector Sales (e.g., Multi-National Firms) Licensing Arrangements	Mass Media Professional Journals Private Sector Promotional Literature
Intersectoral (external to Adopter's sector)	Exhibitions, Shows	Professional Societies (e.g.. ASTM, ASME) Federal Agencies (e.g., USDC, NASA, EPA, SBA, USDA) Private Sector Sales Licensing Arrangements	Mass Media Professional Journals Private Sector Promotional Literature USDC Clearinghouse
Intrasectoral (internal to Adopter's sector)	Trade Shows Observation of Adoption by others	Professional Societies (e.g., AMA, SAE) Trade Associations Agricultural Extension Agent Private Sector Sales Licensing Arrangements	Trade Journals Private Sector Promotional Literature
Intra-Adopter (organization)	Trial Adoption	Gatekeeper Product Champion	In-house Technical Reports

Source: Kranzberg, et al. (1975, I-359)

Table 5 : INFORMATION CHANNELS

L = literature:	books, professional, technical and trade journals, and other publicly accessible written material.
V = vendors:	representatives of, or documentation generated by suppliers or potential suppliers of design components.
C = customer:	representatives of, or documentation generated by the government agency for which the project is performed.
ES = external sources:	sources outside the organization which do not fall into any of the above three categories. These include paid and unpaid consultants and representatives of government agencies other than the customer agency.
TS = technical staff:	engineers and scientists in the organization are not assigned directly to the project under consideration.
R = research:	any other project performed previously or simultaneously in the organization regardless of its source of funding. This includes any unpublished documentation not publicly available, and summarizing past research and development activities.
G = group discussion:	ideas which are formualted as the result of discussion among the *immediate* project group.
E = experimentation:	ideas which are the result of test or experiment or mathematical simulation with no immediate input of information from any other source.

Source : Allen (1966, pp. 2-7) reprinted in Dar and Levis (1974, p. 389).

Figure 2 :

Channel Evaluation Matrix

Criterion / *Channel*	*Accessibility*	*Ease of Use*	*Technical Quality*	*Frequency of Use*	*Weighted Average Ranking*
Literature					
Vendors					
Customers					
External Sources					
Technical Staff					
Research					
Group Discussion					
Experimentation					
Newspapers					
Radio/TV					
Posters					
Puppet Shows					
Bazaars					
Coffee Houses					
Mime/Dance					
Extension Agent					
Leaflets					
Audiovisual Displays					

Source: Dar and Levis (1974, p. 390).

Figure 3 : BENEFITS AND COSTS OF TRANSFER MECHANISMS

ACQUISITION ELEMENTS	ECONOMIC RESOURCES								INSTITUTIONAL RESOURCES							
	Capital		Resources		Labor		Entrepre-neurship		Laws		Government Policy		Political Pressures		Social Traditions	
	B	C	B	C	B	C	B	C	B	C	B	C	B	C	B	C
Sources																
Borrow																
Generate																
Adapt																
Media																
Printed																
Graphic																
Electronic																
Goods																
People																
Channels																
Business																
License																
Join Venture																
Direct Mfg.																
Government																
Trade																
Aid																
Military																
Commerce																
Voluntary Orgs.																
Religious																
Public Service																
Development																

Source: Hansen (1970, p. 169).

What do exist, in the context of international relations, are hypotheses of the following form:

> (The) most effective and efficient transfer of technology is the long-term transfer accomplished through the transfer of people.[4]

> Exports, licensing, and investment do appear to be substitute forms for transferring technology.
>
> There appears to be more transfer of technology through whatever form in high technology goods than in low technology goods.
>
> The higher the level of technology, the more control is retained.
>
> The more complex or more company specific the technology, the more important are exports relative to foreign investment and licensing.[5]

> (There) is a continuum of arrangements which permit varying degrees of efficacy of transfer of technology from the U.S. to the USSR and Eastern Europe. The efficiency of transfer is believed to increase from #1 to #12 as follows:
>
> 1. Sale of patent rights.
> 2. Sale of patent rights and blueprints.
> 3. Sale of patent right, blueprints, and manufacturing know-how.
> 4. The above, plus sale of equipment to build a plant.
> 5. The above, plus construction of a factory to manufacture the product.
> 6. Turnkey project, plus manufacturing rights.
> 7. Turnkey project, manufacturing rights, plus license agreement for transfer of technical know-how on a continuous basis, as it is developed by the licensor.
> 8. All of #7, plus an agreement to train the licensee's engineers in the plant of the licensor.
> 9. All of #8, plus an agreement to train Soviet licensee's engineers in R & D techniques so that they develop the capability to make comparable technological advances in that industry and reduce depedence on Western sources.

10. Production sharing arrangement.

11. Minority ownership in East European enterprise.

12. Minority or majority ownership by Soviet Ministry in a US (European) firm.

In the 1960's the USSR utilized options 1 to 4 only. Most recently they begain utilizing #5 and #6. However, all of these entail the importation of finite bits of technology. Under such arrangements obsolete technology may be imported, or, at least, it may be obsolete by the time the plant is in production and attempting to compete internationally.

With the recent opening up, all of the other options are now possible and in use (only Romania uses #11). As a result we can expect that the speed of transfer of technology into the USSR and East Europe will increase rapidly as compared with the 1960s.[6]

Additional hypotheses are contained in Tables 6 and 7. Their rigorous testing awaits further research.

Table 6 : Hypotheses on International Technology Transfer

(1) and (2) Firms that produce high (low) skill intensive products export to areas that are skill-scarce (skill-abundant) and make foreign direct investment in or license to areas that are skill-abundant (skill-scarce).

(3) Firms exporting high-skill technologies to the developed countries choose between foreign direct investment and licensing arrangements according to: (a) the size of the market. The larger the size of the market, the more likely the firm will choose to make a foreign direct investment; (b) the relationship between the availability of managerial expertise in the countries of export and import. The greater the availability of managerial expertise in the country of export, by comparison with the country of import, the more likely the company will choose to make a foreign direct investment; (c) the differential effect the two are likely to have on the company's competitive position in the market of the country of import; and (d) the relation between interest rates in the countries of import and export. The lower the interest rate in the country of export by comparison with that in the country of import, the more likely the firm will choose to make a foreign direct investment.

(4) Government policies affect the form taken by the international diffusion of technology and thus the extent of national diffusion among developed countries.

(5) Diffusion of the company's technology to potential competitors in the country of import (national diffusion) is most likely when the form of the international diffusion of technology is outward licensing, less likely with outward foreign direct investment and least likely with commodity exports.

(6) There is greater national diffusion of high-skill technologies in developed countries than there is national diffusion of low-skill technologies in less-developed countries.

(7) Government policy is required to induce high-skill technologies to transfer to skill-scarce areas (the LDCs).

(8) A company transferring technology is more likely to transfer the production process than the marketing process, the less skill-intensive the good produced.

Source: Green and Krauss (1973, p. 16).

Table 7

Relationships among Data Variables, Hypotheses and Public Policy Implications

DATA VARIABLES

Firm's Characteristics

(1) Size of firm
(2) Technology costs
(3) Advertising costs
(4) Profits
(5) Product diversification

Technology Transfer

(6) Motivating factors
(7) Mode of foreign involvement
(8) Stage of product life cycle
(9) Type of product transferred

Transfer Environment

(10) Foreign market environment
(11) Transfer adjustment problems
(12) Technological absorptive capabilities of foreign affiliate and its suppliers

Impact of Transfer

(13) Relative profitability as a function of mode of foreign involvement, type of product transferred, and foreign environment.

HYPOTHESES

(1) Small firms with limited financial and managerial resources and larger firms with diversified product lines and relatively large R&D expenditures are more prone to license "unique" or "proprietary" technology than the larger, homogeneous product firm.

(2) Unique and proprietary technologies yield higher rates of return than standardized technology.

(3) Firms often prompted to license unique or proprietary technology for a variety of "second" best reasons or side-benefit affects.

(4) Most "unique" or "proprietary" products are licensed late in the product cycle. (Exceptions have important significance for U.S. policies relative to technology drain.)

(5) Firms with high R&D expenditures and "short-life cycle" products show high incidence of licensing as preferred mode of technology transfer.

(6) Continuing R&D efforts are associated with favorable cross-licensing arrangements, the benefits of which accrue to overall corporate earnings.

(7) Major returns come from fully-owned subsidiaries and industrially-advanced affiliates, but MNCs often prompted to invest in marginal markets to maximize total returns.

(8) Licensing arrangements are generally associated with "sophisticated" foreign partners (ceterus peribus), where indirect benefits often accure from cross-licensing.

(9) Large firms are in a more favorable position to increase profits by packaging technology with marketing and manufacturing, particularly with less sophisticated foreign partners.

(10) Certain firms prefer licensing where foregoing market is small relative to their sales base.

(11) Significant erosion of U.S. technology base may occur when "unique" and "proprietary" technology is *licensed* to, (or in joint venture with, *industrially*-advanced partner.)

PUBLIC POLICY IMPLICATIONS

(1) U.S. Government should a) provide special loans to "small" firms to finance equity holdings b) grant special tax exemptions and other investment incentives to "small" firms licensing technology.

(2) It is in the U.S. national interest to speed the pace of technological development of the less developed countries. Special tax exemptions should be granted for a) R&D expenditures aimed at adapting technology to special needs and conditions of LDCS b) developing design and engineering capabilities in LDCS.

(3) In cases where technology transfer associated with foreign investment is for the prime purpose of avoiding high labor costs or environmental control standards in the U.S., mechanisms to screen such licensing should be devised with a view toward denying any investment credit allowance or other form of tax exemption.

(4) The major path to sustained earnings is to maintain the level of R&D expenditures in industry (financial incentives to include loan guarantees, grants, procurement contracts, R&D tax incentives -- especially to small firms) and allow the corporation to manage technology at home and abroad.

(5) Employemnt displacement effects of investments and technology transfer abroad can most effectively be dealt with through overall economic growth management and more effective trade and employment adjustment policies and measures.

(6) Legislation exempting action from anti-trust laws should be considered to allow "small" companies to pool their efforts in areas involving "major" technological risk.

Source: Foster (1974, p. 70)

NOTES

1. The technology transfer process can also be likened to the diffusion of innovations, in which case this simple model is analogous to the "classical" diffusion model and its variants. See Kelly, et. al. (1975, vol. I, pp. 325-377) and Rogers and Eveland (1975, vol. II, pp. 301-368).

2. Rottenberg (1965, pp. 283-284).

3. See the statements by Mansfield, Caves and Hufbauer in Appendix B for the need for this kind of research and Arrow (1969, pp. 32-34; 1974, pp. 38-43) for hypotheses on differential channel costs.

   The limited empirical work has focused primarily on the mobility of labor as a factor in the transfer process, as in Hindle (1970 and Danhof (1969, 1970), and the effectiveness of alternative information sources on research performance, as in Allen (1966).

4. Cetron (1974, p. 7).

5. Green and Krauss (1973, p. 6).

6. Campbell and Marer (1974, p. 21).

IV. VARIATIONS ON A THEME

Refinements of the simple donor-recipient model take three forms:

1. Construction of a typology of transfer processes
2. Introduction of intermediate stages or participants between the donor and the recipient
3. Disaggregation of the organizational and decision-making structures implied by the words 'donor' and 'recipient'.[1]

The technology transfer process can be classified as either 'vertical', 'horizontal', 'Type I', 'Type II', or 'Type III'.

> (It) is important to distinguish between vertical technology transfer and horizontal technology transfer. Vertical technology transfer occurs when information is transmitted from basic research to applied research, from applied research to development, and from development to production. Needless to say, such transfers occur in both directions, and the form of the information changes as it moves along this dimension. Horizontal technology transfer occurs when technology used in one place, organization, or context is transferred and used in another place, organization, or context. The problems involved in transferring technology from one country to another are quite different when the transfer is vertical as well as horizontal. In general, the difficulties and costs are much greater under these circumstances than if only a horizontal transfer is involved. [2]
>
> Analysis of these two types of technology transfer would show that horizontal transfer is generally an inter-organizational process, whereas vertical transfer generally involves an intra-organizational process. [3]
>
> There are basically three types of technology transfer processes. The first and most simple occurs when the transfer is direct. For example, when one nation or industry utilizes the technology developed by another for the same purpose. . . . The second type of technology transfer is utilization of a technology for a new and different purpose, without basic change. . . . The third type of technology transfer is application of a technology to a different problem. . . .
>
> The Type I transfer is primarily a hardware transfer process, while the Type III transfer is primarily a concept transfer process. The adaptive engineering requirements increase radically as we go from the Type I to the Type III transfer process. [4]

One might also construct additional categories by partitioning technology into

> . . . general technology (information common to an industry or trade), system-specific technology (information concerning the manufacture of a certain item or product that any manufacturer of the item or product would obtain), and firm-specific technology (information that is specific to a particular firm's experience and activities, but that cannot be attributed to any specific item the firm produces).[5]

This is,however, a distinction without a difference unless there are some notable characteristics possessed by, say, the process of a horizontal transfer of firm-specific technology that are not also shared by all the other possible combinations in Table 8.

Ideally, one would like propositions of the form "if the nature of the transfer is 'x' and the type of technology involved is 'y', then . . ." completed and evaluated. To preserve the distinction, it is necessary to show that propositions of this form are neither trivial nor true by definition.

While Hall and Johnson have suggested a number of interesting propositions dealing with the relationship between the costs of transfer and the type of technology involved, they did not specifically treat the nature of the transfer even though from their study of Japan it is clear that the description of the process in these terms changed from horizontal <u>and</u> Type I to vertical <u>and</u> Type III as the U.S. - Japanese coproduction of military aircraft lead to the Japanese design of commercial aircraft for sale on the world market.[7]

The next step in refining the basic model is the identification and enumeration of significant events, phases, stages in, or elements of the transfer process itself. Their particular designation, however, will vary from author to author:

> We have defined technology transfer in terms of the transfer of ideas, knowledge and skills including the capability to adapt a piece of technology to a new environment. If such transfers are to occur, certain key decisions and some minimal set of communication events must take place.

Table 8: A Typology of Technology Transfer Processes

TYPE OF TECHNOLOGY = y / NATURE OF TRANSFER = x	GENERAL	SYSTEM-SPECIFIC	FIRM-SPECIFIC
VERTICAL			
HORIZONTAL			
TYPE I			
TYPE II			
TYPE III			

These events can be used to delineate stages in the transfer process:

(A) A process, product, or technique is invented or developed.

(B) Information from the source of the technology is made available to others, reaching potential recipients.

(C) Information enters a receiver firm.

(D) The information moves through the receiver firm until it reaches those people who will make a decision to act upon it.

(E) The decision to adopt or reject the innovation is made.

(F) Further information is received and a number of problem-setting, problem-solving processes are initiated, potentially involving bi-lateral communication between the source and receiver.

(G) The transfer process ends.

(H) If the transfer process is successful in some sense, the innovation becomes available for utilization.[8]

> (It) is important to distinguish between several phases of the process of technology transfer. The first phase frequently is the export of a new material or product by one country to another. This phase, which Vernon Ruttan and Yujivo Hayami call material transfer, is often followed by design transfer, which is the transfer of desings, blueprints, and the ability to manufacture the new material or product in the recipient country. Finally, there is the phase of capacity transfer, which occurs when the capacity to adapt the new item to local conditions is transferred. Clearly, the last phase -- the phase of learning how to learn as well as to use what others have learned -- it quite different from the earlier phases and much more difficult and costly to achieve. It is a phase that many countries have yet to enter in the more sophisticated areas of technology.[9]

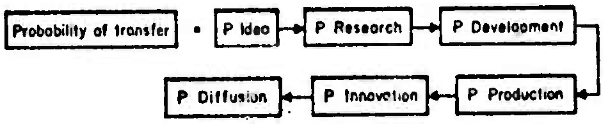
Graphical depictions incorporating some of these ideas (See Figs. 4-12) range from simple probabilistic formulations to elborate representation of the decisionmaking structures of the participants involved.[10] The heuristic motivation for this approach, namely to provide more detailed, albeit generalized, descriptions of the transfer process, must be kept in view. These pictures should not be confused with or interpreted as explanations of the technology transfer process.

Advances in the explanatory power of hypotheses about the transfer process have not, unfortunately, kept pace with the quest for descriptive validity represented by these variations.[11]

NOTES

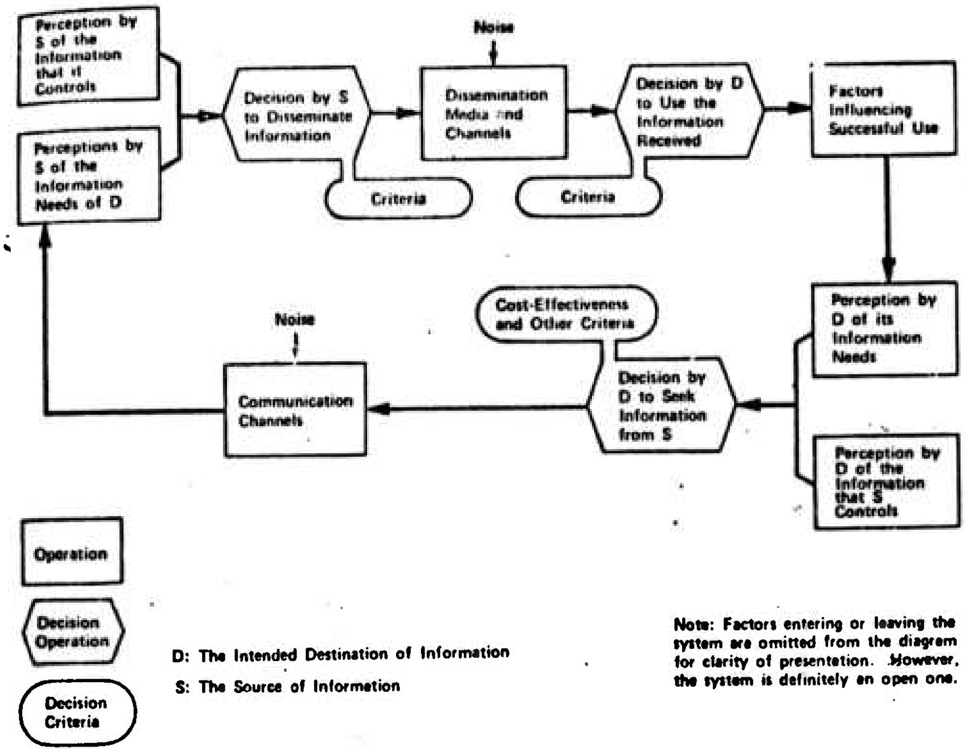
1. This corresponds to the organizational process and bureaucratic politics models of Allison, Halperin and Marshall.
2. Mansfield (1975, p. 372).
3. Chakrabarti (1972, p. 13).
4. Cetron (1974, pp. 6-7).
5. Mansfield (1975, p. 372-3).
6. Hall and Johnson (1970, pp. 306-312).
7. Hall and Hohnson (1967, p. 188).
8. Kohler et al. (197?, p. 171).
9. Mansfield (1975, p. 373).
10. For a more detailed treatment of the approach of the "box and arrow" school of thought to this problem consult Rubenstein (1974, pp. 257-266) and Chakrabarti (1972, 1973), which review some representations down to the level of the individual's thought processes.
11. For a discussion of the concept of explanatory power of different theories see Hempel (1965, pp. 278-282; 1966, pp. 48-49). Validity criteria for representation of behavioral systems are treated in Hermann (1967), Verba (1964) and Crow (1966). For a review of this work and other references, consult Shubik et al. (1972, pp. 95, 101, 116).

Figure 4 : A Sequential Probability Model of Technology Transfer



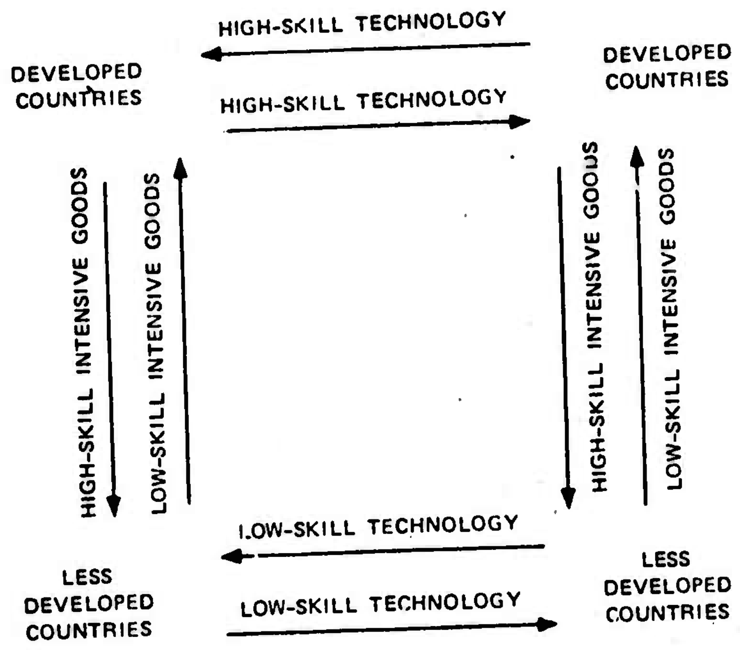
Source: Gruber and Marquis (1969, p. 7).

Figure 5 : A Technology Transfer Flow Diagram



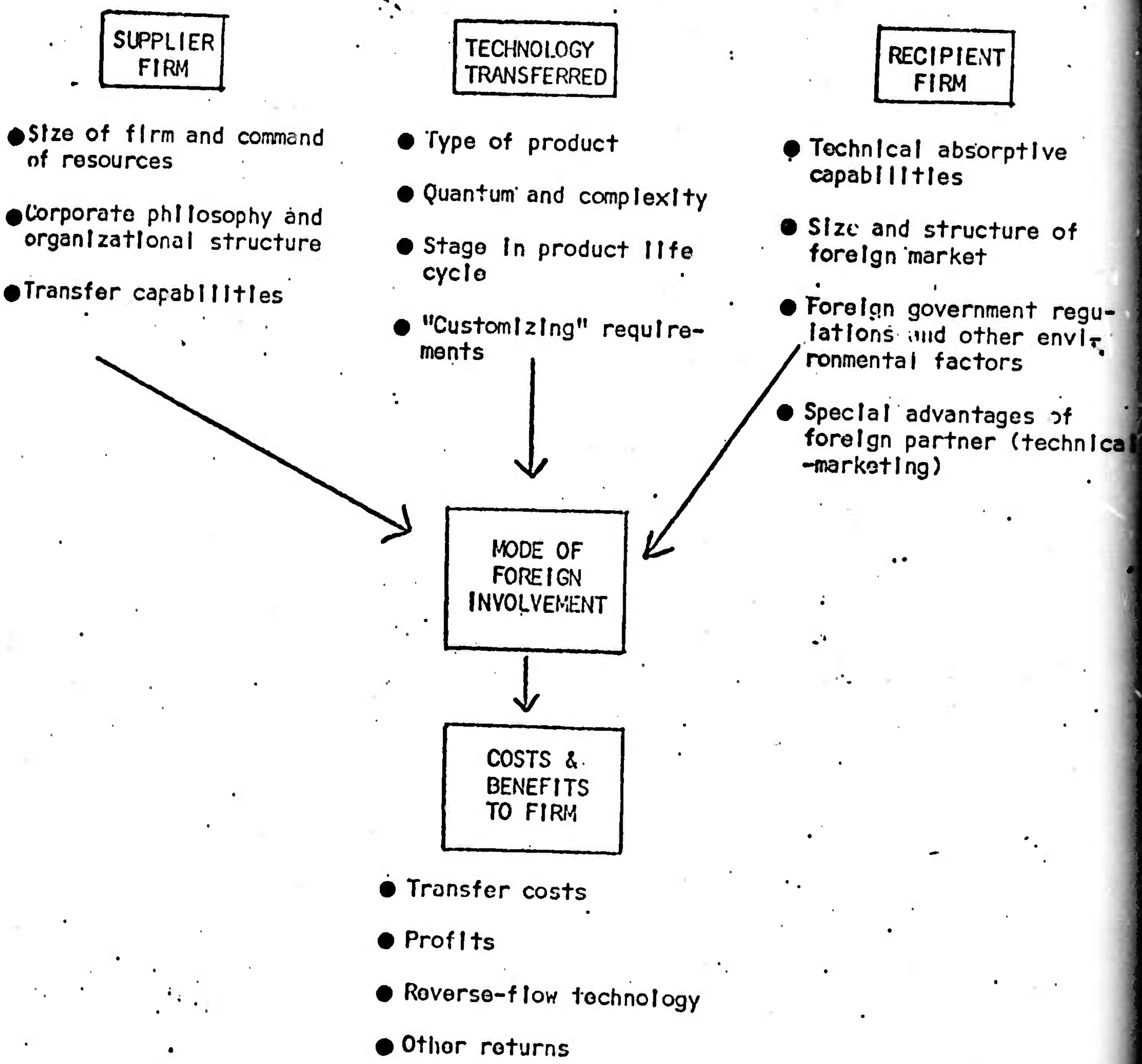
Source: Rubenstein (1974, p. 263).

Figure 6 : The Flow of Technology



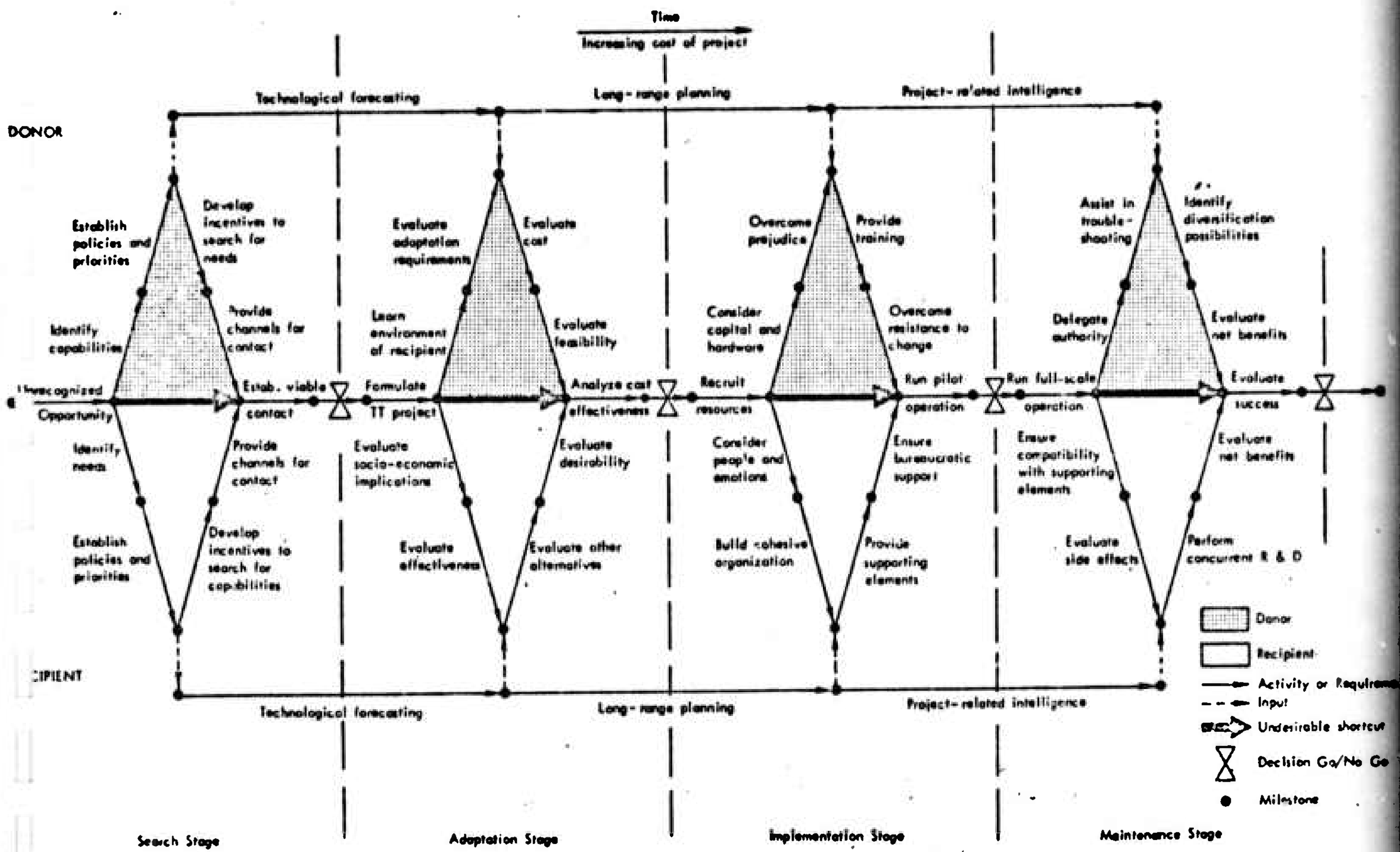
Source: Green and Krauss (1973, p. 10).

Figure 7: Research Hypothesis Model



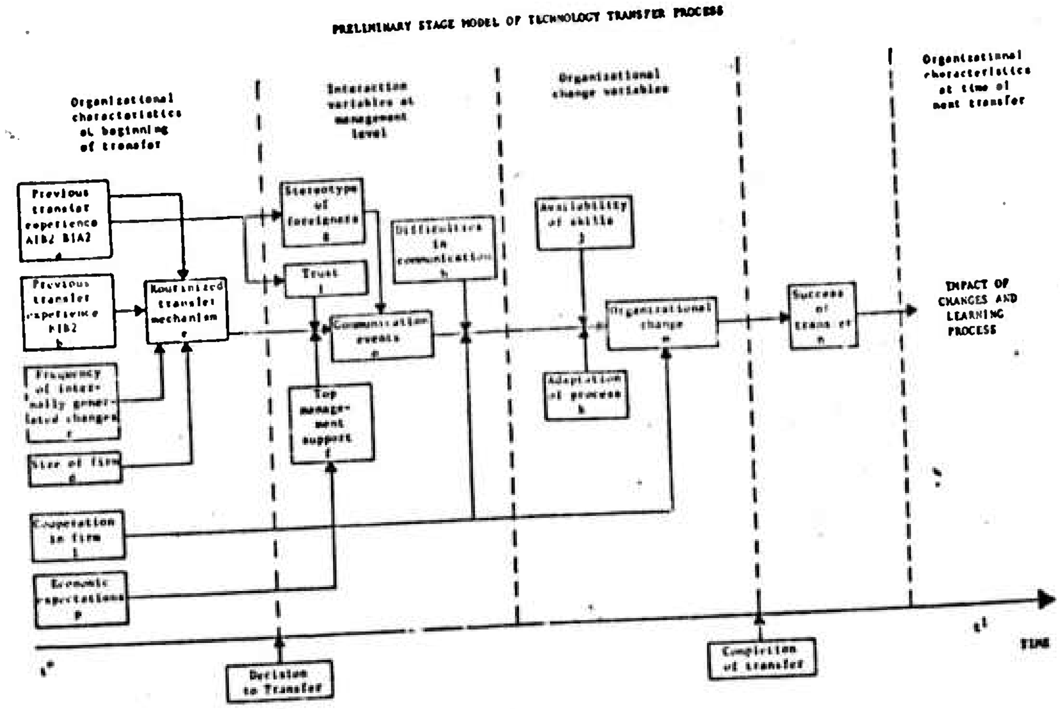
Source: Foster (1974, p. 39).

Figure 8 : A Technology Transfer Model



Source: Bar-Zakay (1970, p. 3).

Figure 9 :



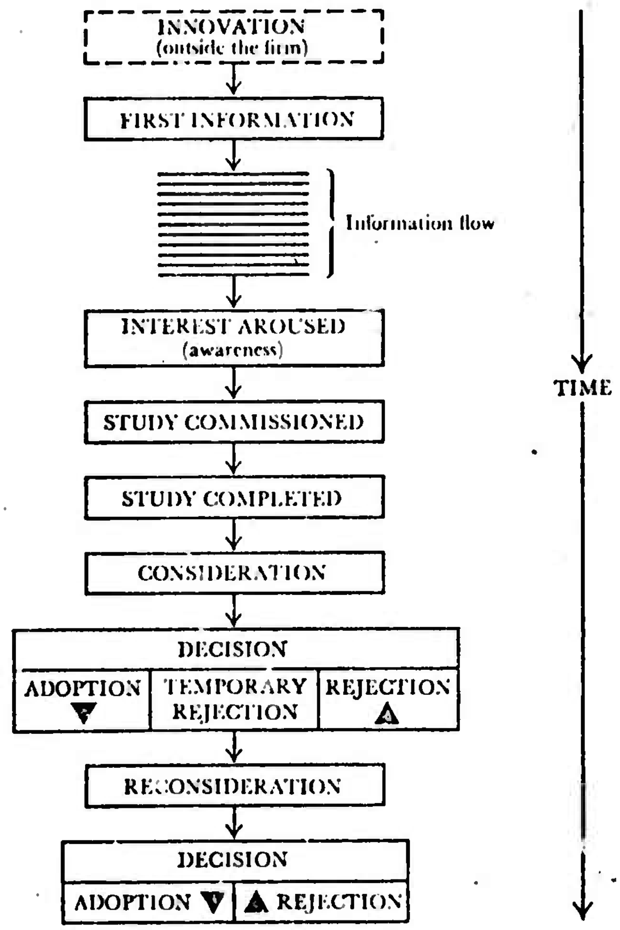
Source: Kohler et al. (1973, pp. 177-8).

The 'model' begins with the decision to enter into the actual transfer process and ends with the availability of the piece of technology at the completion of the transfer. In the following list of variables, a postulated positive or negative influence toward success is indicated by a plus or minus sign. A single-pointed arrow indicates direction of causation; a double-pointed arrow indicates 'is related to' without necessary causation.

a. previous transfer experience of type A1B2. (+)
b. previous transfer experience of type A1A2. (+)
c. frequency of previous changes and adjustments in production program (innovation internally generated). (+)
d. size of firm. (?)
e. routinized transfer mechanism. (+)
f. top management support. (+)
g. stereotype of foreigner (+ or -- depending on nature of stereotype).
h. difficulty in communication due to (1) different world view, management attitude, or value set (–) and (2) language difficulties. (–)
i. trust in foreigner. (+)
j. availability of skills: hiring new staff (+), retraining (–), and learning (–).
k. adaptation of process
(1) transfer with minor technical changes (+).
(2) transfer with major technical changes (–).
l. quality of cooperation of the persons involved previous to introduction of technology. (+)
m. degree of reorganization required in the company:
(1) within existing framework (–).
(2) extension of company (+).
n. dependent variable: success of transfer.
o. frequency of communication. (+)
p. economic expectations of the recipient. (+)

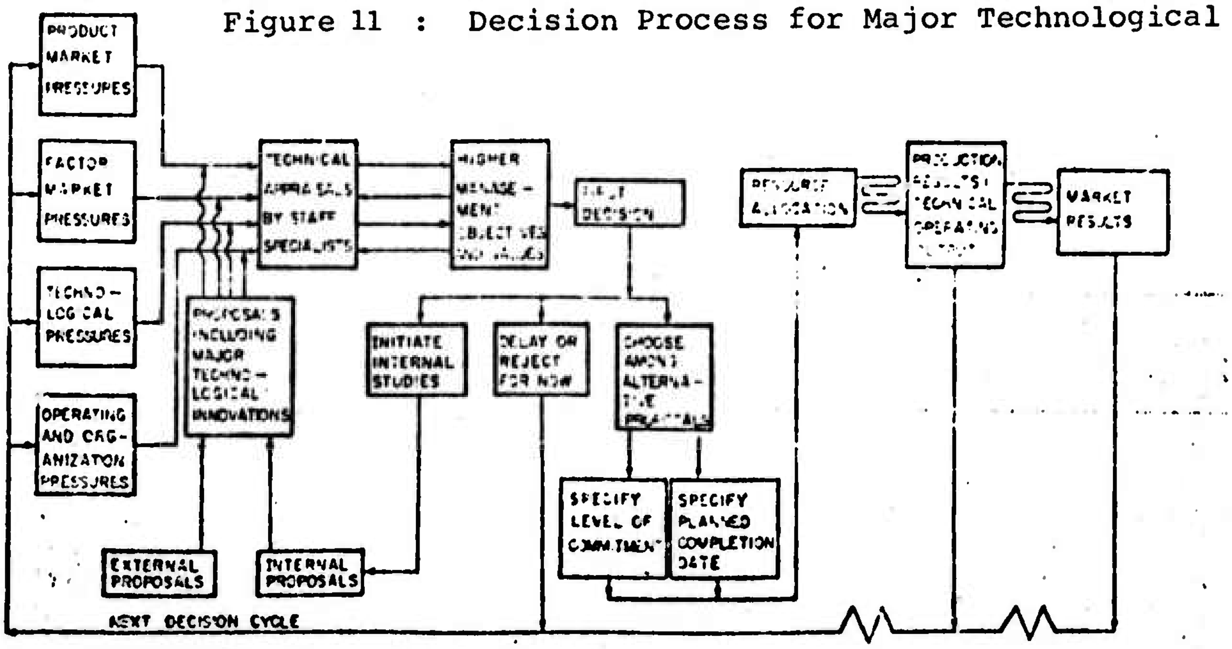
Figure 10 :

The internal process of diffusion within a firm



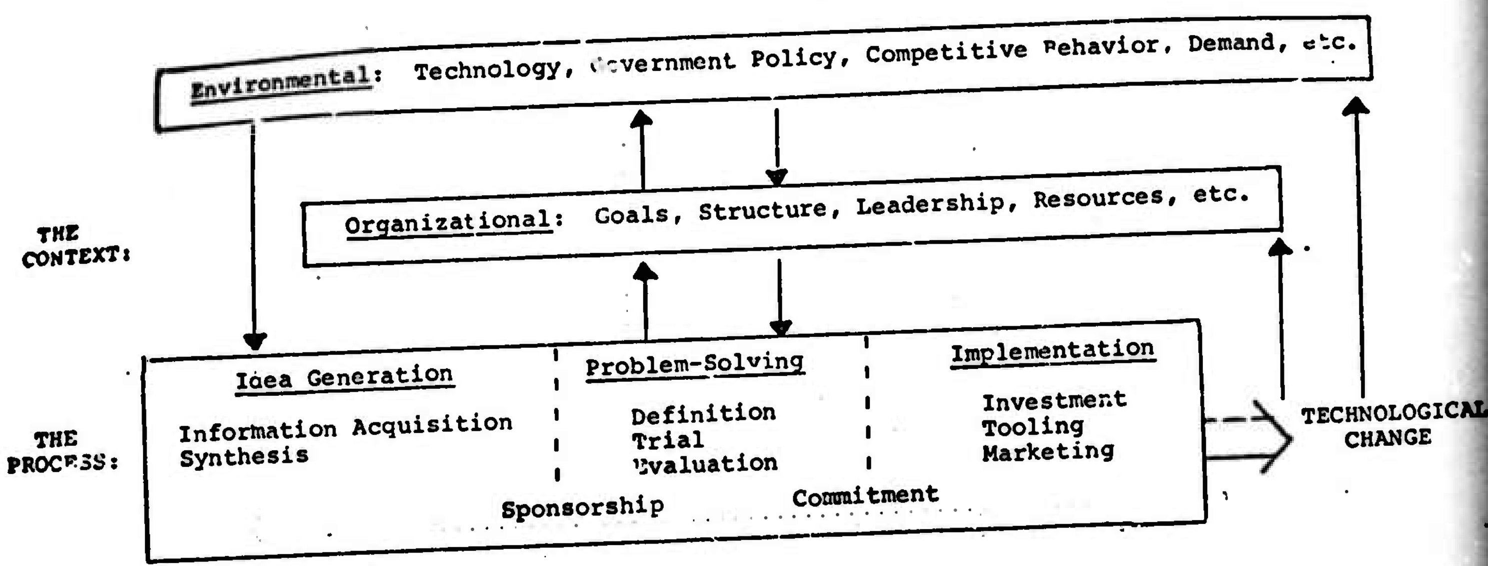
Source: Nabseth and Ray (1974, p. 7).

Figure 11 : Decision Process for Major Technological Innovations



Source: Gold et al. (1970, p. 231).

Figure 12: Conceptual Scheme



Source: Rosenbloom (1975, vol. II, p.179)

V. THE MYTH AND THE METHODS*

There are several methods of analysis that have either been applied or are thought to be of value as an aid in answering questions about the international transfer of technology. These include the following:

1. Case Survey Methods
2. Propositional Inventories
3. International Technological Gatekeepers
4. Economic Analysis of Diffusion
5. Substitution Analysis
6. Spatial Analysis of Diffusion of Innovations
7. Multiple Criteria Decisionmaking
8. Edgeworth-Bowley Box Diagram
9. Utility Theory
10. International Trade Theory
11. Technology Transfer Functions
12. Technology Transfer Index

This review will concentrate on the following points in the synopsis of each method:

1. What is the question or policy area to which the method is addressed?
2. Are there instances of empirical validation of the method?
3. How "macro" or "micro" is its focus? What are the units of analysis involved?
4. What are the likely difficulties in applying this method?
5. What are the implications for the larger program?

Before proceeding, some additional notes of caution are in order. First, the reader should not regard the accompanying explanations of the methods as self-contained. Rather, the presentation should be thought of as an introductory description and not, under any circumstances, the last word. Second, the reader should guard against succumbing to the "myth of methodology", the deceptively alluring notion that if only one had the "right" method, one's question could be answered. [1] In an area where the issues

*Footnotes have been accumulated at the end of each subsection.

are not well-defined, as is the case in this field, the effects of such an attitude will be devastating.[2]

NOTES

1. Kaplan (1964, pp. 24-25). Other "methodological deformations" are discussed in Brewer (1974, p. 16).
2. See Appendix A for comments on the state of the art, but especially those by Caves and Campbell and Marer.

1. The Case Survey Method

In his review of this field, Charles Douds, among others, discussed the value of the case study approach as a research method, given the current state of the art.

> Early in the development of a research field - such as technology transfer - it is appropriate that the case studies be of a chronological, narrative character, given that there is little theory upon which to draw and that there is a great deal of uncertainty about the nature of the phenomena involved. They are more useful if they also treat the behavioral, organizational, and environmental aspects. However, the insights obtained are strongly dependent upon the training, skill, perceptiveness, and other such personal characteristics of the case writer, as well as the reader. In the discursive or 'soft' literature the writer often seeks to persuade the reader to some attitude or action. The writers' role is intentionally an active one. In this 'midway' literature - midway to providing the verifiable predictive capability associated with scientific theory and engineering practice - the case writer's role is not intended to be active. But it must necessarily be so, for he can report only a finite amount of information from the endless possibilities of what could have been reported. Such cases can help to structure a field. One can discover factors common to several cases, and relationships among these factors may be suggested. A single case may suggest an important element or relationship not observed or not reported in other cases.
>
> Case study information may be of use in generating alternatives for action as well as propositions for testing. Case studies do not provide tests of propositions and, in aggregate, form a somewhat hazardous basis for determining the frequency of occurrence of various factors. One usually has little information available to determine how the sample of cases examined compares to the population of potential cases, and infrequently knows the methods and criteria used to select the material reported. There may also be a bias present in many cases studies: It is hardly worth the considerable effort required to collect the data unless the case is notable in some regard.
>
> There is another use of the case study approach. One may have a theoretical model that structures or explains the relationship between certain conditions or variables in a range of situations. This model is more than a listing of factors-to-note existing prior to, or developed during a case study.

The case is prepared paying particular attention to the factors contained in the model. The input filter is made explicit and the reader, as well as the author, can judge if the model does not fit the situation. If it does not fit then the model must be reworked. If it fits then further studies testing the model may be worthwhile. If it appears to fit the situation, at best it can only be said that it fits this ONE situation.

It is to be noted that extreme cases are particularly useful in generating insights or 'conceptually testing' propositions and models. Parallel cases with different outcomes provide similar opportunities if they have been developed comparably. However, it is extremely difficult to determine when cases are 'parallel' and to assure that their preparation is comparable.[1]

In spite of the problems it presents, the case study approach is the method of analysis suggested by expert opinion in their recommendations for further research in this field, independent of the particular policy area of interest.[2] What is also needed is a procedure for bringing diverse case studies together under a common conceptual framework so that findings can be cumulative. The case survey method is, in light of the existing body of research in this field, the preferred aggregation technique.[3]

> Conceptually, the case survey method is quite simple. The analyst wishes to distill the lessons from a set of local case experiences. He prepares a set of questions that ascertain the outcomes of interest and the alternative determinants of those outcomes. The possible answers to the questions are carefully structured and defined so that the analyst, after reading the case materials, can readily determine the most appropriate response. The answers to these questions are determined in the same manner for each of the cases that have been selected for study.
>
> * * *
>
> The essential step in an aggregative review is a clear statement of purpose and the development of a theoretical model of the phenomena under investigation. All concepts cannot be studied, nor can all alternative concepts be tested. Necessarily, the reviewer will have his own intuitive sense of what factors are important and what variables are interrelated. To say a first step is the development of a theoretical model is often to say only that the reviewer must make explicit to himself and to others his purpose and his theoretical conception. To make that knowledge external to himself will permit its refinement and assist in making the practical choices among the many variables that could be considered and how they should be defined, choices forced by constraints of time and money. The steps to be taken in that context are:[4]
>
> - <u>Identification of concepts</u>. The aggregator must articulate the concepts which he particularly wishes to explore through the medium of the case studies.
> - <u>Specification of concepts</u>. These concepts must be broken down into detailed questions which can be applied directly to the case studies.
> - <u>Identification of case variables</u>. The aggregator must identify and define those variables which make case studies unique.
> - <u>Generation of the checklist</u>. The checklist is a questionnaire which combines those questions which specify concepts and those which identify case variables. When applied to a case study, it yields what the aggregator wishes to know about that case study.
> - <u>Trial run of the checklist</u>. The checklist must be tried in practice and freed as much as possible of inadequacy and ambiguity.

- Final run of checklist. Here the checklist is applied to the whole number of case studies intended for aggregation.
- Analysis. The data resulting from the final run are analyzed with a view to correlating inputs into the innovation process with outcomes therefrom.
- Introduction of case variables. The case variables are introduced at this point, both as a source of further analytical correlation among the data and also as a check for possible bias in the conclusions [5]

In addition to the ability to aggregate various characteristics of individual case studies, the case survey has three other features that can address major methodological problems in conducting a systematic review of research literature. These features are: the establishment of the reliability of the method; the ability to differentiate weak and strong responses on the part of the reader-analyst; and the use of explicit rejection criteria for excluding some studies from the review. [6]

While the case survey method "offers an excellent opportunity to assess...(policy issues) where case studies are important,...its limitations should also be noted."

The most important limitation is that the results of the survey are of no better quality than the quality of the original case studies. Although the case survey can be used to assess that quality explicitly, the substantive conclusions about 'what the literature says' are obviously still limited by the level of that quality. Second, the case survey method, in its focus on aggregating general lessons, may not give sufficient attention to the possibly unique factors of an individual case. The tradeoff here may be similar to the tradeoff in behavioral research between experimental and clinical research. Only the latter may provide a full appreciation of the individual case; however, the former must be relied upon more heavily if the goal is to create generalizations across individuals. Third, the case survey method may be more appropriate where the primary concern is with assessment (e.g., has decentralization succeeded?), and not necessarily with the discovery of process (e.g., how does one decentralize a service?). Inquiries about process can be fruitfully carried out only where the existing case studies themselves have focused on process, and where the key to understanding the process is fairly simple (e.g., noting the concurrence or sequence of several events). [7]

Although all of this may seem simple and straightforward in theory, its application, even in the instance of generating a list of questions, can be quite another matter. The difficulties confronted by several leading researchers in the area of the international diffusion of technology on just this point are enlightening.

> To keep the research as far as possible on a similar footing in each country and on each subject, it was necessary to meet regularly - on average three times a year - during the period of the inquiry. At the earlier meetings much effort was devoted to reaching a single research design which could be applied to all of the technologies; that is to say it was hoped to enumerate a set of common questions which would be analysed in the same way and thus permit, in principle, generalisations concerning diffusion of technology. After several efforts this approach had to be abandoned. On closer inspection, different technologies suggested differences in the range of questions most likely to throw light upon the process of diffusion. Moreover, the research design had to be tailored to the information which was likely to be available in the participating countries, and this differed from one technology to another.[8]

Their reflections on the matter also prove noteworthy.

> In a project like this which has extended over a long period - more than five years - much experience has been gained which may be of help to others entering the same field of research. We can ask ourselves: what would we do differently if we were starting the project now?
>
> In the beginning we discussed whether we should try to get information about diffusion patterns for a large number of new processes, or whether we should confine ourselves to just a few, to be studied in depth. Taking into account all the difficulties described in interpreting diffusion rates, the line we chose of selecting a limited number of processes seems to have been the right one, given the resources available. But the attempt to get most of the data required from individual firms rapidly reached a limit of strongly diminishing returns. In some countries it was just too difficult. If we were to start again, we would probably rely much more on information from other sources, such as producers and sellers of new equipment and licence-holders, and have it confirmed by a few companies. Establishing good contacts with such producers seems to be a better approach, and obviously the more one can rely on published data the better, although when it comes to new processes inevitably such data will be scarce indeed. Another approach would have been to go deeper into a limited number of companies, but then one would probably have had to give up the idea of making any king of industry-wide or country-wide generalisations.

As to methodology, this study was undertaken in two consecutive stages, a procedure which was dictated by financial considerations. If there had been no such restriction, it would have been better if we could have given more time at the beginning, to discussions on how to analyse our material. Then it might have been easier to compare diffusion of the various processes in detail.[9]

Since the case survey method is still in its formative stages of development, there have been very few applications of particular relevance. One preliminary attempt at aggregating the results of research on innovation met with mixed results.[10] There were problems in selecting a representative sample of case studies, making sure that the case writers recorded all the essential information transfers in the history of an innovation, and once again, designing a checklist that had a high level of definition and a low level of abstraction. On the other hand, a less rigorous (only 1 reader-analyst, cases chosen on the basis of availability and the personal perceptions of the analyst) attempt to generalize across the case studies of technology transfer between countries, between applications and instances of missed opportunities listed in Tables 9-11 reached the following conclusions:

> Transfers to developing countries are primarily of the incidental type.
> Transfers between applications are about equally distributed between incidental and organized cases.
> The cases of missed opportunities of transfer could have been avoided had there been a stronger capability for organized transfer in the developing countries.
>
> Missed technology transfer cases include both inter-country and inter-application transfer (e.g. solar energy to India).
> In some cases the donor of technology lost an opportunity (e.g. carbon fibers in Britain) and in others the recipient is the loser (e.g. sugar in Cuba).
> The reasons for lack of transfer range from political (agriculture-Egypt) through bureaucratic (land-Belgium) to lack of knowledge (Sisal-Tanzania).
> Successful technology transfer can be achieved across thousands of miles and may constitute a failure across short distances.[11]

In light of the current state of the art and expert suggestions for further research, the case study approach and survey method merit preferential application to the larger program of study.

Table 9 :

CASES OF TECHNOLOGY TRANSFER
(between countries)

No.	From: Context I	Capabilities in Context I	To: Context II	Needs in Context II	Transfer Agent	Type of Transfer
1	ITALY	Fiat manufacturing and marketing	YUGOSLAVIA	Car production. Export.	Corporation	Organized
2	PHILIPPINES	Developed "miracle rice"	THAILAND	Grow more rice.	Research Institute	Incidental
3.	U.S.A.	Nuclear weapons technology	RUSSIA	Nuclear weapons technology	Individuals	Organized
4	GERMANY	Volkswagen manufacturing and marketing	BRAZIL	Car production. Export.	Corporation	Unknown
5	FRANCE	Color television technology	RUSSIA	Color television technology	Government	Organized
6	TURKEY	Training facilities	JORDAN	Higher Education	University	Incidental
7	U.S.A.	Soyabean drink technology	GUYANA	High protein content food.	Corporation	Incidental
8	ISRAEL	Biological pest control	U.S.A.	Fight Florida Red Scale	Research Institute	Incidental
9	BRITAIN	Textile mills technology	JAPAN	Industrialization	Individuals	Organized
10	U.S.A.	Advanced medical and welfare services	GABON	Medical techniques	Individuals	Incidental

Source: Bar-Zakay (1974, p.513).

Table 10 :

CASES OF TECHNOLOGY TRANSFER
(between applications)

No.	From: Context I	Capabilities in Context I	To: Context II	Needs in Context II	Transfer Agent	Type of Transfer
1	Nuclear irradiation	Destroys life	Fruits infection	Destroy insect and bacteria	University	Unknown
2	Space research	Satellite earth survey	Earth resources	Find new resources	Government	Incid[illegible]
3	Osmosis process	"Filter salt"	Desalination	Reverse Osmosis	Individuals	Incidental
4	Biological research	Enzymes technology	Detergent industry	Remove protein stains	Corporation	Organized
5	Polymer research	Polyox reduces turbulent flow	New York Fire Department	More water through hoses	Research Institute	Incidental
6	Teleoperators	Unmanned Moon exploration	Human augmentation	Help handicapped	Government	Incidental
7	Air Force	Helicopter development	Toy industry	New toys	Individuals	Organized
8	Nuclear research	Study of the atom structure	Leakage in pipes	Locate leakage	Research Institute	Incidental
9	Search for new structural materials	High modulus lightweight in composites	Soldiers armor	Protect life at light weight	Corporation	Organized
10	Computers	Fast storage and retrieval of information	Urban planning	City scape simulation	University	Organized

Source: Bar-Zakay (1974, p. 514).

Table 11 :

CASES OF TECHNOLOGY TRANSFER
(missed opportunities)

No.	From: Context 1	Capabilities in Context 1	To: Context 11	Needs in Context II	Reason for Missed Opportunity	State of Opportunity
1	Solar-energy technology	Low cost energy	INDIA	Low cost energy, Fertilizers.	Lack of analysis capabilities	Hopeful
2	JAPAN	Continuous welding process	U.S.A.	Modern shipping industry.	Lack of forecasting	Too late
3	ISRAEL	Modern agriculture technology	EGYPT	Modern agriculture technology	Political	Still Hopeful
4	U.S.A.	Composites research	TANZANIA	Sell more sisal	Lack of analysis capabilities	Still Hopeful
5	International sugar technology	Increase sugar production	CUBA	Increase productivity and export.	Lack of analysis capabilities	Still Hopeful
6	BRITAIN	Carbon fibers technology	U.S.A.	Carbon fibers	Inability to take high risks	Too late
7	Machine Bull	Computers technology	FRANCE	French owned computer technology	Lack of forecasting and planning	Too late
8	SIERRA Leone	Iron-ore deposits	World	Iron	Lack of analysis capabilities	Too late
9	BELGIUM	Land available near port	BELGIUM	Land for industry	Bureaucratic	Still Hopeful
10	World industry	Imports	BRAZIL	Export diversification	Lack of analysis capabilities and planning	Still Hopeful

Source: Bar-Zakay (1974, p. 515).

NOTES

1. Douds (1971, pp. 126-127).
2. See Appendix B for a discussion of the role of case studies in further research on the international transfer of technology.
3. Other variants of the case survey method include the "focused comparison" method and the "disciplined-configurative approach" (George and Smoke, 1974, pp. 94-97, 515, 640-641).
4. Lucas (1974, p. 2).
5. Gayer (1975, pp. 3-4).
6. Yin and Heald (1975, p. 5).
7. Ibid., pp. 17-18.
8. Nabseth and Ray (1974, p. 14).
9. Ibid., pp. 315.
10. Gayer (1975, pp. 35-36). To my knowledge, the only "successful" policy-oriented application of the case survey method is the work of Smoke and George.
11. Bar-Zakay (1974, pp 516-517).

2. Propositional Inventories[1]

Once a set of potentially researchable questions has been formulated for the particular research area of interest, a procedure for organizing the hypotheses or propositions which purport to answer the questions posed is desirable.[2]

The propositional inventory is one such "systematic means of recording observations, hunches, empirical findings, anomalies, a priori assertions based on theory or any other statements that can potentially form the theoretical underpinnings" for the data collection to follow.[3]

> The role of propositional inventories -- or sets of related propositions -- in the field of international technology transfer is crucial because of the many ambiguities and contradictions found in the many assertions, recommendations and policy statements which abound in the field. Re-casting such statements in rigorous propositional form can help to clear up such ambiguities, etc., and accentuate key variables and measurements to which attention should be addressed.[4]

The basic conceptual, as well as operational unit forming the structure of the research is the "proposition", a statement describing the relationship between a dependent variable, y, and an independent variable, x, which usually takes one of the following forms:

1. Most x's are y's.
2. If x occurs, then y occurs.
3. The value of y is influenced by the values of x_1, x_2, etc.

An example of a propositional inventory is given in Table 12 and additional illustrative propositions in Tables 13 and 14.[5]

The raising of potentially researchable questions and the preliminary statement of propositions are only first steps in the development of indicators which contribute to the construction of instruments for the collection of data. (See Figure 13). Detailed operationalizing, testing and reformulation of the propositions still must be done.

> Some of the propositions will be simple two-variable assertions which can be supported or rejected by fairly straightforward statistical or other means. Some will be suitable for contingency tables and the associated tests, depending on sample sizes and the nature of the variables. For some descriptive propositions (e.g., "who are the decision makers for technology transfer in LDCs?"), frequency counts, histograms, rank orderings, or simple listings may be indicated. For those propositions involving multiple independent

TABLE 12: AN EXAMPLE OF THE PROPOSITION INVENTORY

A. Factors which Influence Interaction between Source and User of Technology

1. User experience with past successful transfer by the source.
2. User perception that source personnel understand and have expertise in implementation problems.
3. Level of success in reducing perceived social distance between source and user personnel.
4. Extent to which a user can share the cost of R&D with other organizations and reduce risk.
5. Awareness by user of a need for new technology.
6. Assessment of each others' technical capabilities.

B. Source Factors which Influence the Probability of Successful Technology Transfer

1. Level of acceptance by the scientists of the responsibility of Science" for the development effort in their country.
2. The incorporation of scientifically adept businessmen or business-oriented scientists into the source organization.
3. The extent to which the source is evaluated according to some criteria of profitable utilization of research.
4. The extent to which the source accepts diffusion and utilization as partly their responsibility.
5. Scientists' perception of how they can use their knowledge for economic development.
6. Project selection criteria of the source.

C. User Factors which Influence Probability of Successful Transfer of Technology

1. Level of awareness by user of innovational alternatives.
2. Level of initial commitment to the innovation.
3. Perceived effect of the innovation at each level of the organization, on the organizational goals at that level.
4. Perceived need to change technology.
5. Active role of top management in change process.
6. Technical expertise of decision group.
7. Change potential of current technology.

D. Factors which Influence Effectiveness of Intermediaries in the Transfer of Technology (e.g., Equipment Brokers and Distributors)

1. The extent to which both the user and source value the knowledge and expertise of the intermediary.
2. The ability of the intermediary to understand the viewpoint of both source and user.
3. The level of intermediary's knowledge of the source and user technical ability.
4. The level of technical training of the intermediary.
5. Ability to apprehend adaptive possibilities of the technology.

Source: Rubenstein (1975, p. 30).

TABLE 13 :

SOME ILLUSTRATIVE PROPOSITIONS ON TECHNOLOGY TRANSFER

1. Product and process innovstions require different types of coupling mechanisms. Operating scientists and engineers are most important in the utilization of process type technologies, whereas top managements have to be sold on the idea of product innovations (Chakrebarti).

2. Formally structured methods (e.g., appointing liaison agents) will be less likely to result in high levels of innovation than informally evolved methods of directing the transfer of technology where application areas are similar (Bean).

3. An organizational innovation process may be under-structured so that progress is retarded by a lack of direction and it may be over-structured so that progress is retarded by over direction (H. C. Young).

4. The timing of the initial contact and subsequent maintenance efforts are equally important in successful coupling in a project of relatively short duration (e.g., under 8 months) (H. C. Young).

5. A multiple liaison mechanism (or coupling of several groups between the source and user of the innovation) operating at all phases of the technology transfer process and at all levels of both source and user organizations, is an effective means of insuring high utilization rates of new technology (J.E. Ettlie).

6. The more new technology is divergent from the technology the user has utilized in the past, the more need of a formal liaison/coupling arrangement between source and user (Jedlicka).

7. Pairs of groups that value collegial growth tend to have fewer problems, but this has to involve both groups (Douds).

8. Individuals and groups that preferred the "confrontation" method of joint decision making and conflict resolution perceived fewer communication problems than those who preferred the "forcing" or "smoothing over" methods. (Barth).

9. Liaison agents whose organization affiliations and reporting relations permit the client a relatively high degree of control over the liaison agents' actions will be more effective than those over whom the clients have relatively little control (Bean).

10. Each transition point between phases of implementation (e.g., from shakedown of the technology to production) results in potential communication gaps (Ettlie).

11. The more aggressive the coupling group is in determining what the user wants, the more likely the coupling group will be effective (Jedlicka).

12. Where a single source of a new technology is coupled with several users of the innovation, it is more effective to locate major coupling functions in the source organization. On the other hand, where several sources of technology are coupled with a single user, it is more effective to locate major coupling functions in the user organization (E. C. Young).

13. Several forms of control are used that directly affect the management of a European laboratory by their American parent organization: An American is appointed as a laboratory managing director; American scientists are frequently sent to overseas labs to head specific departments or groups temporarily; and promising managers from foreign labs are sometimes brought to U. S. labs for a temporary training period (Forster).

14. The strongest single indicator of the level of communication effectiveness is the level of technical respect one person or group has for another (Douds).

15. When a client has high expected benefits from an innovation, he places an emphasis on the involvement and technical competence of the liaison agent (Davig).

16. If some members of each organization involved in a coupling arrangement are conversant in the primary languages (including technical) of the other organizations or groups, a more effective coupling arrangement will result. Common language increases the problem formulation capability of each organization in terms of the others and it lowers status barriers (perceived status differences) between organizations (E. C. Young).

Source: Rubenstein (1974, pp. 250-251).

TABLE 14 : More Propositions on Technology Transfer

a) R&D organizations depend upon a relatively small number of people to communicate with outsiders and bring independent new information into the organization where it is passed on to others.

b) Scientific/Technological information can be transferred between organizations (or their units) unchanged, but in the process of application it is usually adapted, changed or added to.

c) The recognition of a need is most often essential in bringing about the research-engineering interaction.

d) Face-to-face communications are more effective than other modes in problem solving.

e) Because of the different classes of information and levels of detail needed, multiple information channels are used in a complementary manner (e.g., oral + written, commercial + professional).

f) Different channels are used for maintaining general awareness than for solving (specific) problems.

g) The orientation and behavior of individuals in acquiring scientific and technological information exhibits greater variance among catagories when classified by their functional responsibilities than when classified by the industries with which they are associated.

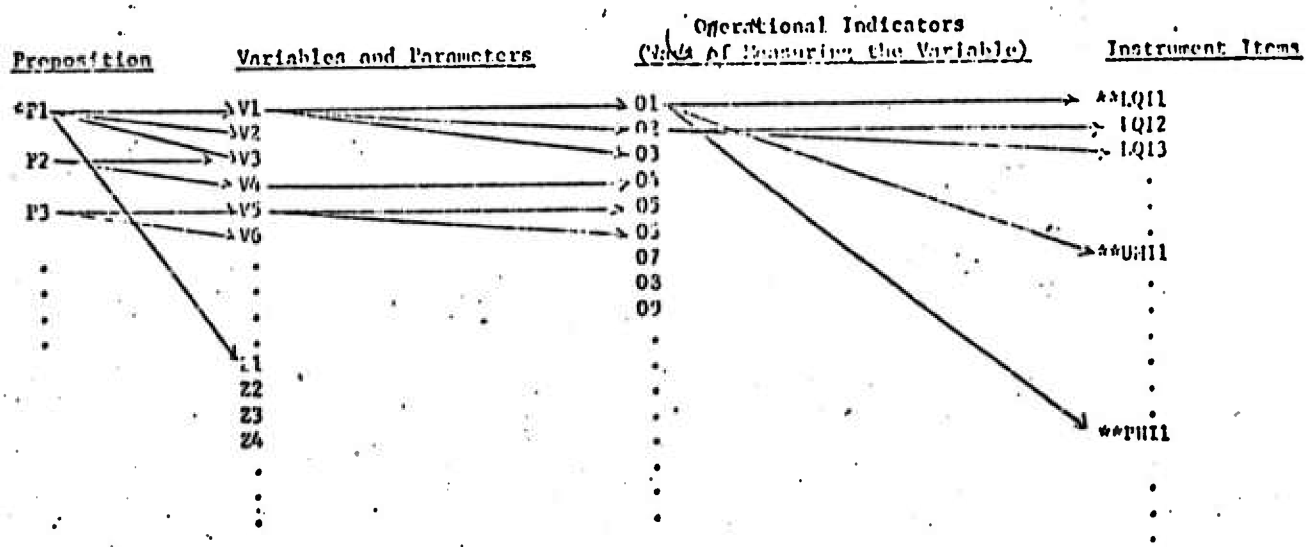
h) Printed and verbal channels are perceived as equally important for the acquisition of new technology.

i) Increased accessibility to and familiarity with an information channel tends to increase its perceived importance.

j) Scientific and technological information experiences its earliest transfer by people-to-people interactions rather than through formal publications.

Source: Rubenstein, A.H. A Real-Time Study of Technology Transfer in Industry, POMARD, Northwestern University, Jan. 1969 pp. 11-16, and reprinted in Goldhar (1971, pp. 54-55).

Figure 13: THE PROPOSITION-ITEM MATRIX



*e.g., P1: V1 = f(V2, V3, Z1)

**e.g., LQI1 = Item one on Long Questionnaire Instrument
UNI1 = Item one on Unobtrusive Instrument Sub-Package
PHI1 = Item one on Project History Interview Protocol

Source: Rubenstein (1975, p. 37).

Figure 14 : An Approach to Proposition-Based Field Research

RESEARCH AREA OF INTEREST

POTENTIALLY RESEARCHABLE QUESTIONS

POTENTIALLY TESTABLE PROPOSITIONS

VARIABLES AND DEFINITIONS

INDICATORS FOR THE VARIABLES

RESEARCH INSTRUMENTS

FIELD STUDY DESIGN

FIELD STUDY

PROPOSITION TESTING

RECYCLE*

* Of course recycling occurs at every stage and a typical design procedure does not necessarily occur in the sequence indicated.

Source: Rubenstein (1975, p. 34).

variables, suitable statistical methods (can) be employed in seeking correlation, direction of influence,[6] or other degrees of association with the dependent variable.

The entire approach is summarized in Figure 14.

NOTES

1. This discussion assumes the reader is familiar with "the method of hypothesis". See Hempel (1966, pp. 17-18).

2. A question is defined to be unresearchable if it is not "feasible to adequately define the variables and provide indicators to measure them or it may not be feasible to gain access for the required measurements." Rubenstein (1975, p. 33).

3. Ibid., p. 31

4. Ibid., p. 28.

5. An inventory of generalizations about the diffusion of innovations is contained in Rogers and Shoemaker (1971, pp. 346-385).

6. Ibid., p. 34.

3. International Technological Gatekeepers

"Conventional wisdom" has it that technology transfer is a "people process."[1]

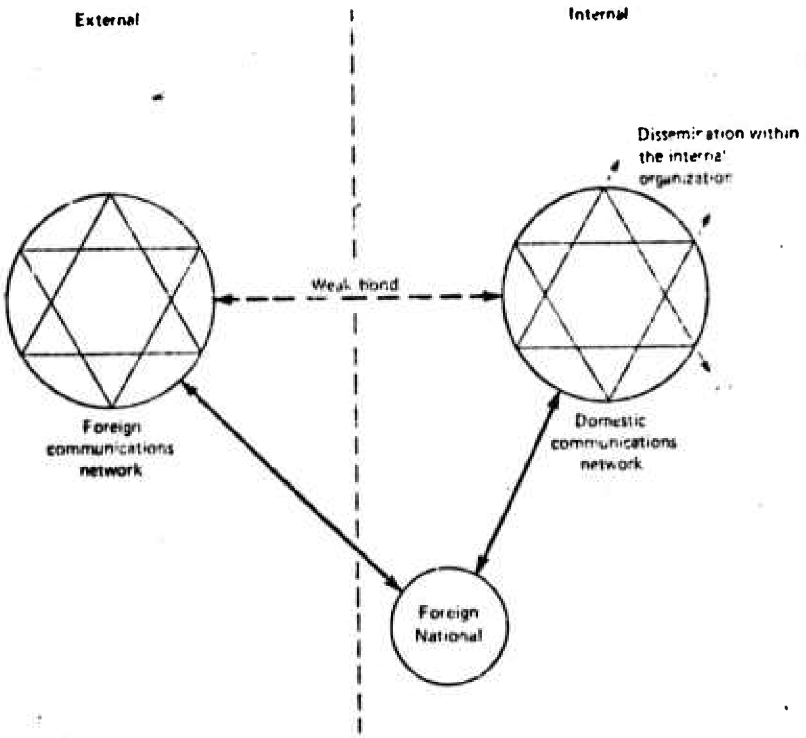
This is not surprising, since, from the point of view of the recipient, the transfer of technology can be regarded as the adoption of an innovation by an organization and the value of "product champions" and "change agents" have long been recognized in this context.[2] This observation leads to the question of whether some people are more important than others in the international technology transfer process. The literature on communications theory argues that there is one type of individual worth examining in some detail, the international technological gatekeeper.

The function of the gatekeeper is to mediate "between his or her organizational colleagues and the world outside and effectively couple the organization to outside activity."[3] In essence, they serve as internal consultants to the average member of the organization on external sources of information.

> Figure 15 illustrates the basic concept of the gatekeeper. The internal environment constitutes the organization, area, or community in which information is needed. The external environment constitutes the total pool of knowledge and expertise outside the organization. People, material, and information flow across the system's boundary.
>
> Empirical evidence shows that certain individuals in an organization or community perform the role of 'communication stars', that is people who are frequently turned to for advice, formal or informal leadership, and technical information. Further, these 'communication stars' form a close network of communication both formal and informal within the organization. Information required by one member tends to diffuse to the other members of the organization and strong communication bonds become establishes. The stars within the circles represent the gatekeeper communication networks of the internal and external environments.[4]
>
> The foreign national couples both these networks and in effect, performs a role of gatekeeper to the gatekeepers.

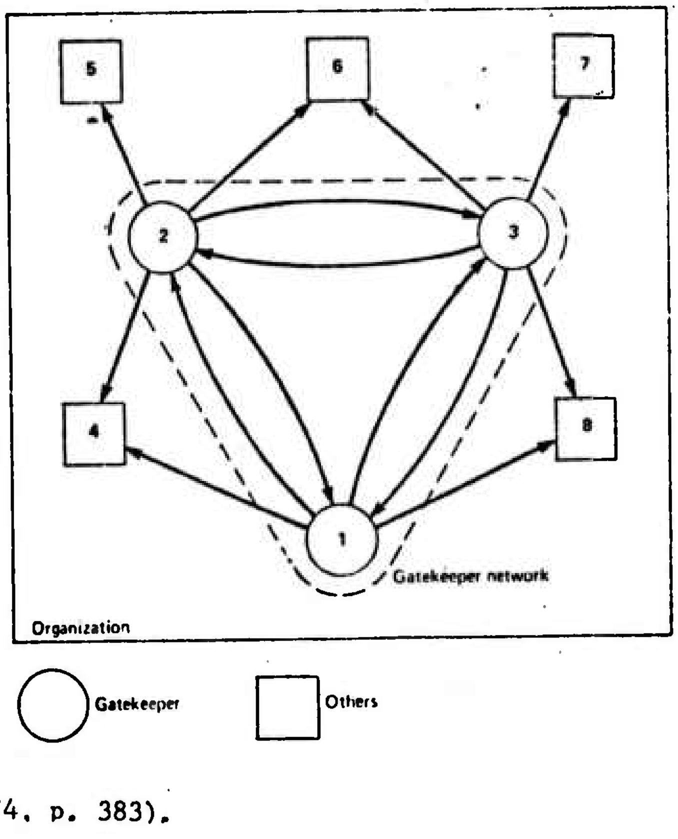
Figure 16 is a further elaboration of the gatekeeper network and its relationship to other members of the organization. Information acquired by the gatekeepers tends to circulate through the gatekeeper network and diffuse outwards to non-network members.

FIGURE 15 : THE INTERNATIONAL TECHNOLOGICAL GATEKEEPER



Source: Dar and Levis (1974, p. 381).

FIGURE 16: INTERNAL GATEKEEPER NETWORK



Source: Dar and Levis (1974, p. 383).

Since "the practical application of this communication process may... make the difference between a successful or unsuccessful project," it is important to identify those "key people who may well be an integral part of the gatekeeper network."

Table 15 contains a list of characteristics of key people that may assist in that endeavor. A more rigorous approach is to measure the communications bond between individuals in different organizations.

> "In order to compare the amount of communication among organizations, an index had to be developed. There are many possibilities for such an index, none of which are completely satisfactory. The one which has been chosen is one which should allow valid comparisons to be made with a minimum of distortion to the data. The index is based on the number of individuals in any organization, who are reported as communication partners by those in another organization.
>
> $$C_{ij} = K \frac{n_{ij}+n_{ji}\;1-e^{\frac{-N_j}{10^2}}}{N_i N_j}$$
>
> where:
>
> C_{ij} = strength of the communication bond between organization i and organization j
>
> K = a scale factor, in this case $K = 2 \times 10^2$
>
> n_{ij}; n_{ji} = number of individuals in organization j or i who are named as communication partners by their counterparts in organization i or j
>
> N_i = number of respondents in the larger of the two organizations
>
> N_j = number of respondents in the smaller organization
>
> The constant term is simply a scale factor to avoid the use of very small decimal fractions, while the exponential term is a correction factor to offset the effect of wide differences in size of organization. "5

This approach has proven successful in <u>identifying</u> the international technological gatekeepers at the level of the individual, based on a sample population at the Irish Agricultural Institute, and for the organizations comprising the entire research and development community of the Republic of Ireland. (See Figure 17.) Their specific contribution to the success or failure of particular projects was, unfortunately, not noted. This extension should be made.

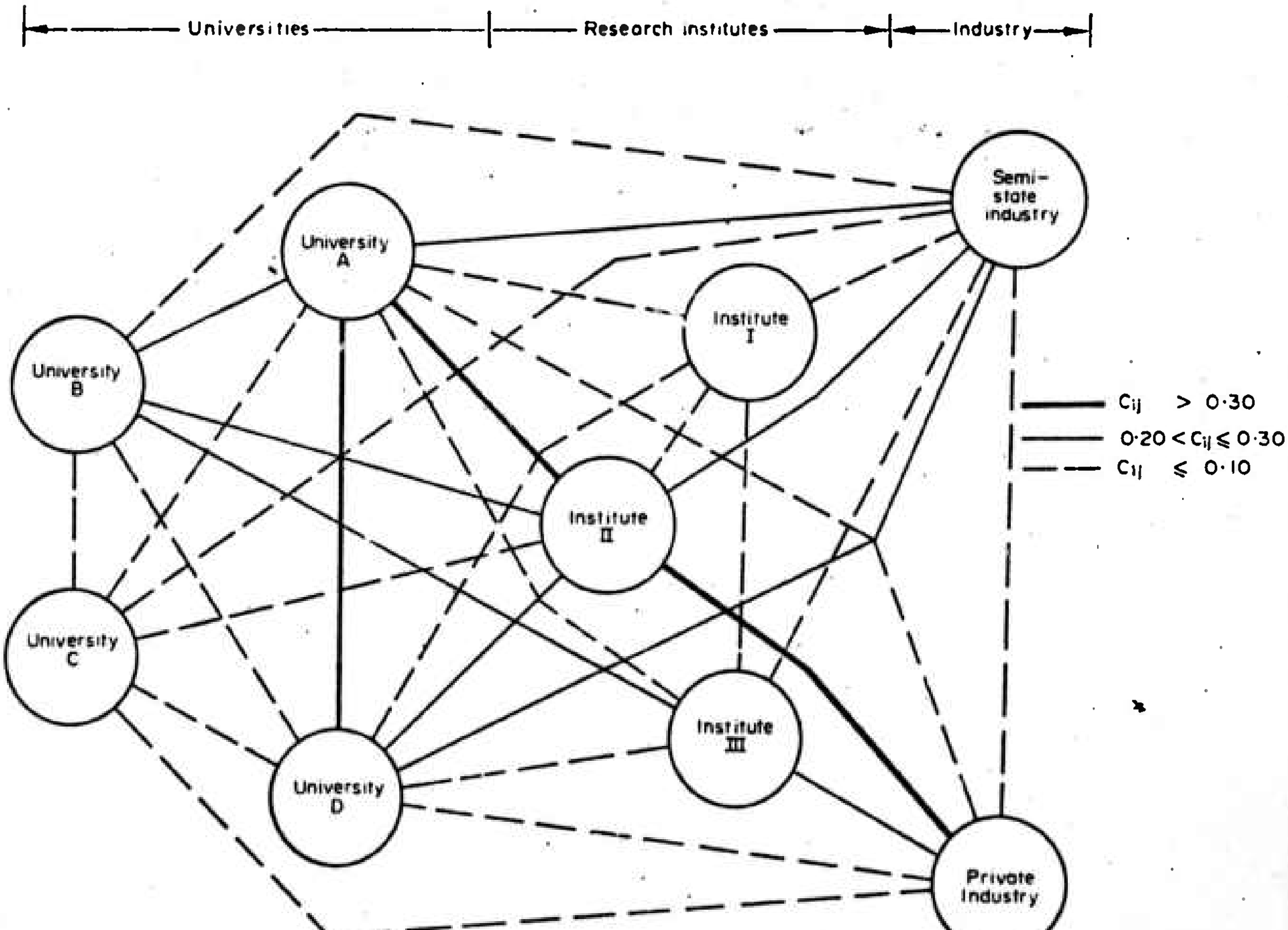
TABLE 15: Identifying the Key People

Characteristics:

1. Read far more. "hard literature."
2. Broader ranging and longer term relationships with technologists outside their organization.
3. Important direct contributor to the organization's technical goals.
4. Produce significantly greater number of papers and more likely to be among those cited when a chief engineer or chief scientist is asked to name key people.
5. High proportion of first-line supervisors and second-line supervisors.
6. Personal characteristics:
   a. Feel accomplishment from helping others
   b. Less emphasis on congenial people
   c. More emphasis on competent people
   d. Preferred to map broad features of a problem
   e. Felt accomplishment when doing innovative work
   f. Lesser feeling of accomplishment from meeting or exceeding standards
   g. Scored no higher than colleagues in creative ability tests
   h. More formal education (more Ph.Ds).
7. Their primary motive for helping people is not that they feel it will help them get ahead in the organization. It is possible that helping colleagues provides them with a measure of job satisfaction.
8. High in innovation, productiveness, and usefulness.
9. History of being able to influence others in organization.
10. Seem to work better under time pressure.

Source: Dar and Levis (1974, p. 386).

FIGURE 17: Level of Monthly Contact Among Major Research Institutions



Source: Allen (1973, p. 45).

NOTES

1. See Appendix C for more "conventional wisdom" about technology transfer.

2. Chakrabarti (1972), Rogers and Shoemaker (1971, pp. 227-248).

3. Allen (1971, p. 3) cited in Dar and Levis (1974, p. 380).

4. Dar and Levis (1974, p. 381-383).

5. Allen (1971, 1973).

4. Economic Analysis of Diffusion

What are the factors which affect the adoption of a technical innovation and determine the rate of its diffusion?[1] The following list was compiled based on case studies of numerically controlled machine tools, the use of special presses in paper-making, tunnel kilns in brick-making, the basic oxygen steel process, the Pilkington float glass process, the application of gibberellic acid in malting, the continuous casting of steel, and the diffusion of shuttleless looms:

(1) Technical applicability: the new process may not be applicable, for technical reasons, to the whole range of a company's or a country's productive operations. Diffusion might be confined within some 'technically feasible' maximum or a technological ceiling', which could be only a fraction of total production, although often this is difficult to calculate unambiguously.

(2) Profitability: it was assumed that the economic advantages which make the new process profitable relative to alternative, more conventional, technologies would help to explain its diffusion. This, however, is not an easy concept to define, let alone measure. Factors costs varying between countries, the age and the technical standard of the existing equipment, the product-mix and many other considerations can influence profitability calculations.

(3) Finance: lack of financial resources might delay the diffusion of new processes, even when their profitability has been established.

(4) Size, structure and organisation: large companies may, for a number of economic, technological, or other reasons, behave differently from medium-sized or small firms; the organisation and structure of the industry as well as of the companies (for example, their foreign associations, or the vertical or horizontal integration of companies within a holding company) can also have a marked effect on diffusion, and may be particularly important in explaining international differences. High concentration, or a monopoly position, may create conditions which can influence innovation or diffusion either way.

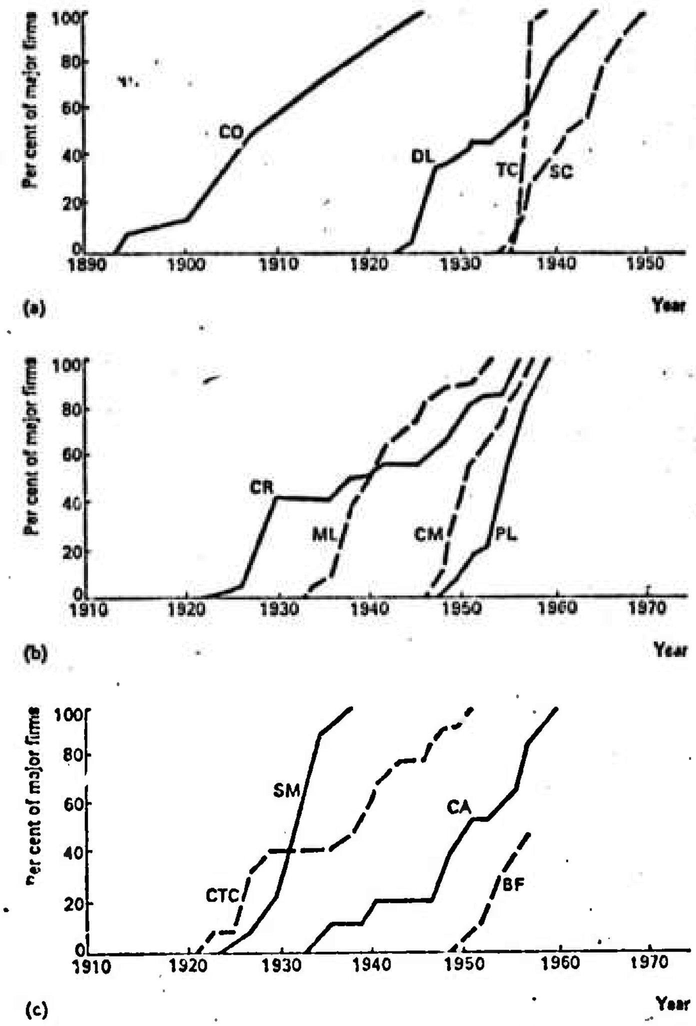
(5) Other factors, such as research and development activity, access to information, the labour market (availability of certain skills), licensing policy, the market situation and, more precisely, the growth of demand for the product as well as the competitive position with special regard to import competition, all illustrate the wide range of factors which could contribute to explaining differences in the speed of diffusion.

(6) Management attitudes: these are, unfortunately, the most difficult to assess or quantify, but, nevertheless, they may be as important as economic factors in influencing the rate of adoption of new methods. Attempts have been made by the authors of some of the chapters to quantify management attitudes.[2]

To the extent that there can be said to be a theory (in the sense of "a systematically related set of statements, including some lawlike generalizations, that is empirically testable") which purports to explain why innovations diffuse, as contrasted with a listing of factors to note, then the work of Edwin Mansfield comes closest to satisfying these criteria.[3]

> Four principal factors seem to govern how rapidly the innovation's level of utilization approaches this ultimate, or equilibrium level: (1) the extent of the economic advantage of the innovation over older methods or products, (2) the extent of the uncertainty associated with using the innovation when it first appears, (3) the extent of the commitment required to try out the innovation, and (4) the rate of reduction of the initial uncertainty regarding the innovation's performance. Based on these factors, a simple mathematical model has been constructed to explain the differences in the rate of diffusion shown in Figure 18. This model is based on the following four hypotheses:
>
> First, as the number of firms in an industry adopting an innovation increases, it is assumed that the probability of its adoption by a nonuser increases. This assumption seems reasonable because, as experience and information regarding an innovation accumulate, the risks associated with its introduction grow less, competitive pressures mount, and bandwagon effects increase.
>
> Second, the expected profitability of an innovation is assumed to be directly related to the probability of it adoption. This seems reasonable because the more profitable the investment in an innovation promises to be, the greater will be the probability that a firm's estimate of its potential profitability will compensate for the risks involved in its installation.

Figure 18: Growth in the percentage of major firms that introduced twelve innovations, bituminous coal, iron and steel, brewing and railroad industries, 1890-1958



(a) By-product coke oven (CO), diesel locomotive (DL), tin container (TC), and shuttle car (SC).

(b) Car retarder (CR), trackless mobile loader (ML), continuous mining machine (CM), and pallet-loading machine.

(c) Continuous wide-strip mill (SM), centralized traffic control (CTC), continuous annealing (CA), and high-speed bottle filler (BF).

Note: For all but the by-product coke oven and tin container, the percentages given are for every two years from the year of initial introduction. Zero is arbitrarily set at two years prior to the initial introduction in these figures (but not in the analysis). The length of the interval for the by-product coke oven is about six years and for the tin container it is six months. The innovations are grouped into the three sets shown above to make it easier to distinguish between the various growth curves.

Source: Mansfield (1971, p. 284).

Third, for equally profitable innovations, the probability of adoption is assumed to be smaller for innovations requiring relatively large investments. This is because firms will be more cautious before committing themselves to large, expensive projects, and they will have more difficulty in financing them.

> Fourth, the probability of adoption of an innovation is assumed to be dependent on the industry in which the innovation is introduced. For equally profitable innovations requiring the same investment, the rate of adoption in one industry might be higher than in another because firms in that industry are more inclined to experiment and take risks, the industry's markets are more keenly competitive, or the industry is healthier financially."[4]

In order to test these hypotheses, Mansfield constructed the following simple, deterministic model of the diffusion of the j-th innovation in the i-th industry,

> Letting $\lambda_{ij}(t)$ be the proportion of firms not using the innovation at time t that introduce it by time $t+1$, I proposed that
>
> $$\lambda_{ij}(t) = f_i(P_{ij}(t), \Pi_{ij}, S_{ij}, \ldots), \qquad (1)$$
>
> where $P_{ij}(t)$ is the proportion of potential users of the innovation that have introduced it at time t, Π_{ij} is the profitability of installing this innovation relative to that of alternative investments, and S_{ij} is the investment required to install this innovation as a percentage of the average total assets of the firms. In other words, the model assumes that the probability that a non-user will use the innovation between time t and $t+1$ is dependent on the proportion of firms already using the innovation, the profitability of using the innovation, and the investment required to install the innovation.
>
> Assuming that $\lambda_{ij}(t)$ can be approximated adequately by a Taylor's expansion that drops third and higher-order terms and assuming that the coefficient of $P^2_{ij}(t)$ in this expansion is zero, it can be shown that the growth over time in the number of firms having introduced the innovation should conform to a logistic function. Specifically,
>
> $$P_{ij}(t) = [1 + e^{-(L_{ij} + \phi_{ij} t)}]^{-1}. \qquad (2).$$ [5]

This is shown in Figure 19, where

$$P_{ij}(t) = m_{ij}(t)/n_{ij} \qquad (3)$$

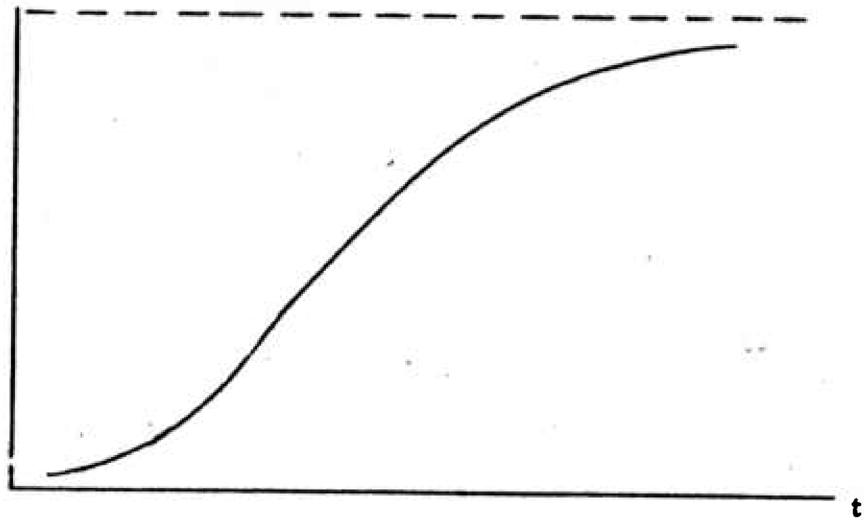
and $m_{ij}(t)$ is the number of firms introducting the innovation and n_{ij} is the number of firms in the industry.

As others have pointed out, many phenomena, including the spread of disease and rumors take on this same general S-shaped curve. The heuristic motivation is as follows:

> The logistic curve is an intuitively pleasing model for the rate at which the percentage of an innovation to total market grows through time. In the early years, while still new, information about the innovation is scarce, making it riskier and therefore growth is slow. As it becomes more widespread the information becomes better and the growth rate increases. When it approaches its equilibrium use, (in terms of the total market) the growth again slows. Thus we would expect a growth "profile" similar to the S-shape of the logistic curve.[6]

Figure 19: The Logistic Curve

$$P_{ij}(t) = \frac{m_{ij}(t)}{n_{ij}}$$



Source: Mathematica (1974, p. II-29).

Examination of equation (2) reveals that

the rate of imitation depends only on ϕ_{ij},
and on the basis of our assumptions,

$$\phi_{ij} = b_i + a^1\Pi_{ij} + a_2S_{ij} + Z_{ij}$$

where the a's and b's are parameters and Z_{ij} is a random error term. [7]

Tests of the theory, based on both stochastic and deterministic versions of the model, do lend support to the preceding hypotheses and, in particular, to the statement that

> the probability that a firm will introduce a new technique is an increasing function of the proportion of firms already using it and the profitability of doing so, but a decreasing function of the size of the investment required. [8]

These models have been extended to an assessment of the impact of international technology transfer on the U.S. share of the worldwide market for the diffusion of numerical controls and semiconductors.[9]

The approach is not without its critics, however, since it does not include, as Mansfield recognizes, the extent of the dependence of the firm on the innovation.[10]

The problem in constructing diffusion diagrams is the choice of a reasonable basis of comparison.

> In studying the diffusion of a new technique in the paper or steel industry for instance, the data can be related either to the total production of paper or steel, or to the number of firms in the industry. But problems at once arise: either the new technique may never be suitable for certain types of paper or steel, or it may improve over time, so that while it is unsuitable for parts of the production or some types of firms initially, it will be suitable later on. Examples of the first case are special presses, which have never been suitable for some types of paper, and tunnel kilns, which cannot be used for certain grades of clay. The basic oxygen process illustrates the second case, since initially it could not be adapted for big plants, for producing specialised steels, or for processing high-phosphoric ores. A third problem arises with numerically controlled machine tools, which can be used to produce parts of many different products that are, however, not clearly definable, and a fourth (relating both to the numerator and the denominator) is how to fix a starting date for commercial operation of a new process which has been improved over a long period, but initially could be used only in some types of plant. When is it possible to say that the process has really become an innovation in the Schumpeterian sense of the word?

These problems can be solved in different ways, all more or less arbitrary. In the chapters on continuous casting and tunnel kilns, a 'technological ceiling' was assumed for each country, but the problem of defining the ceiling remained. For the diffusion charts to provide a definition, either the process must have been in use for a very long time, or some sort of theoretical definition is needed. Another solution is to ignore that part of the production or production equipment which is definitely unsuitable for the new process. This was done for special presses and tunnel kilns, but, of course, here too there is an arbitrary element.

Yet another way of handling the problem is to use Mansfield's method of counting only those firms that have already introduced the new process. Only fairly well established processes can then be studied, and those firms that prefer to retain the old process, possibly because it too has been improved, are not taken into account, thus precluding deeper analysis of the procedure behind the choice of new processes. Examples of competition between a new process and an improved version of the old can be found in tunnel kilns...in basic oxygen steel...and in continuous cooking in pulp production.

Even if all the firms that have not introduced the new technique are eliminated from the analysis, the problem remains of how to analyse the case where there is a choice of innovations. This has affected many companies in the computer field, and there are examples of it in the studies of new methods of steel-plate marking and cutting in shipbuilding.

In general, comparisons of diffusion patterns between processes and between countries require the utmost care. The arbitrary assumptions which are unavoidable mean that conclusions based on casual inspection can easily be quite wrong. In the literature of diffusion, sigmoid curves, representing the development through time of the number of firms using the new technology, or the volume of production or capacity, have been widely used, but two distinct questions remain. The first is simply whether such curves give a good statistical fit to the observed data. (When the diffusion process is manifestly incomplete and the number of observations from the past is small, one may not be able to distinguish with any confidence between the first part of a sigmoid curve, the beginning of an exponential expansion and a straight line.) Secondly, even if one is satisfied that the curve is a good pictorial representation of the facts, how should this particular shape be interpreted?[11]

Futhermore, to argue that "estimates of profitability must be tempered by some allowance for uncertainty" is insufficient.[12]

> "To say that major innovational decisions are based on profitability expectations adjusted for the estimated probabilities of adverse outcomes may be unobjectionable, and may even be correct of adverse out but it is certainly unenlightening. As an 'explanation' of past decisions, it offers nothing more than a tautology: i.e., if an innovation was adopted, management must have expected it to be sufficiently profitable; and if not, not. And as an empirical 'test' of such expectations, it is hardly more helpful to demonstrate that the innovations which survive and achieve eventually wide diffusion are those whose utilization has been associated with profitability. Serious analysis surely requires digging deeper."[13]

Introducing more detailed representations of the decision-making structure and more refined definitions of the capacity concept would appear to be steps in the right direction. (See Figure 11 and 20).

These exploratory models of managerial decisions concerning the adoption of major innovations do differentiate between additions to available capacity, displacement of functioning facilities and the replacement of capacity withdrawals.[14]

They do not, however, incorporate the multidimensional nature of the concept of industrial capacity, which has, even in the narrow use of the term, at least ten possible interpretations, none of which reflect the possible tradeoff between production rate, throughput time and utilization rate as shown in Figure 20.[15]

Even attempts to allow for

> "the inevitable judgmental elements in early managerial evaluations of new technologies, which are likely to limit the potentials of purely mechanistic bases for forecasting eventual diffusion rates,"

have had mixed results.[16]

We have attempted to explain and understand the international differences in rates of adoption of a new production technology, the basic oxygen process as applied to steelmaking. Our investigation has been dominated by two hypotheses:

(a) that most of the differences between firms, and perhaps to an even greater extent between national industries, can be explained by objective differences in the economic environment within which these firms or industries must operate;

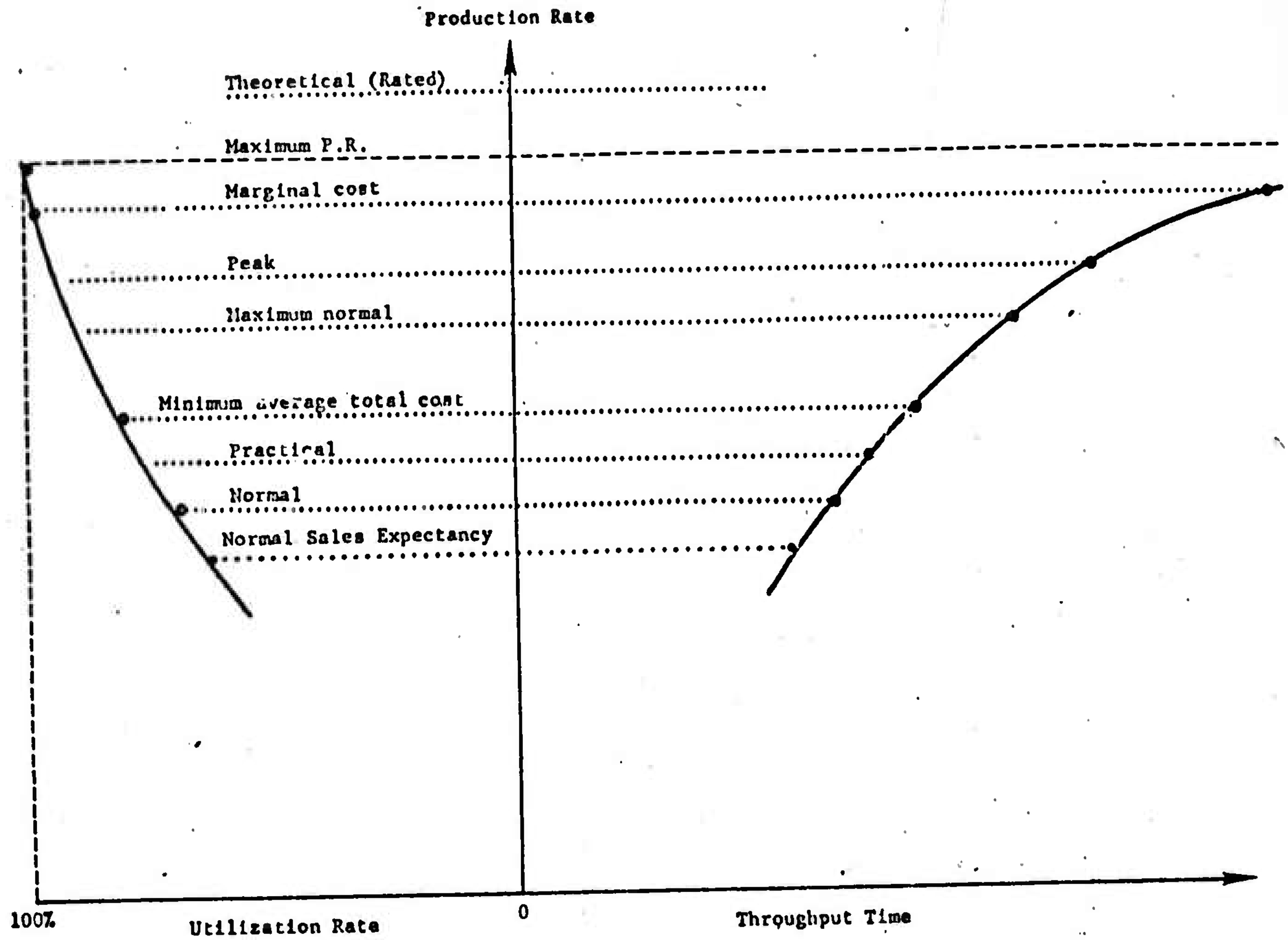
(b) that some of the differences observed between firms or national industries are attributable to such non-economic factors as differences in management styles and motivation.

These two hypotheses are not necessarily mutually exclusive. It is entirely possible that both are correct to some degree and are needed to achieve a reasonably adequate understanding of the diffusion. For example, it is entirely possible that all firms respond eventually in a reasonably rational fashion to objective economic signals, but the rate of response may differ because of managerial or motivational differences. Of course, even these differential rates of response may not be strictly rational in a narrow economic or efficiency sense.

In attempting to assess or test these hypotheses, we initially surveyed the aggregate evidence and the technological history of the process. We concluded that neither gave us any basis on which to do even a preliminary sorting or assignment of relative weights to the two hypotheses. In particular, we specifically rejected simple counting exercises as legitimate tests of these concepts; adequate testing required substantially more detail than could be provided by diffusion curves or similar devices.

* * *

Figure 20: Measures of Industrial Capacity



Source: Stoller (1966, p. 15).

Accordingly, we attempted to calculate a more direct measure of managerial motives and aspirations. For this purpose we adapted some techniques of factor analysis, as commonly applied to psychological or educational testing. Specifically, we construed certain of the values taken from balance sheets and income statements (those that seemed to be particularly under the control of individual managements) as being 'test scores' indicating possible orientations of the managements involved.

It would be extravagant for us to claim that our attempt to measure motivation was completely successful; it was handicapped by the same difficulties which handicap the measurement of more conventional or straightforward economic effects. However, we did create a measure which seemed reasonably plausible, particularly for the years 1962, 1963, and 1964, when major cyclical or other economic disturbances, largely irrelevant to measuring long-run effects such as motives, were mainly absent. Furthermore, we found that our motivational index correlated reasonably well with investment behavior.

Our index of management motivation, which we called an 'aggressiveness score' was dominated as an explanation of investment behaviour only by cash flow, which has long been considered basic to the timing and stimulation of steel industry investment. Capacity utilisation, another variable commonly found to be influential, was at best only equal to the aggressiveness score in explaining investment behaviour. In short, the steel companies and national industries in our samples seem particularly sensitive to cash flow, but if other important influences are discernible, these would appear to be capacity utilisation and something akin to managerial aggressiveness.

* * *

We also tested our aggressiveness index as an explanatory variable for diffusion. Unlike investment, however, we did not discover a discernible influence ir almost any plausible formulation of the functions. Not only were the coefficients insignificant, but they also more often than not had a negative sign, thus quite clearly running counter to hypothesis.

We tested our aggressiveness score only with our individual firm data or samples, on the grounds that only at that level did measures of managerial motivation seem reasonably plausible. At this individual firm level, however, the second best (to some investment or market expansion measure), and in some instances the best, explanatory variable of diffusion was a measure of productivity (output per number of employees). Productivity could, of course, be regarded as a proxy for management effectiveness or motivation; this would be particularly appropriate when included (as in our equations) with measures of the age of existing productive capacity. In short, were were not able to identify at the firm level any managerial effect attributable to our direct measure of aggressiveness, although 1962 productivity, operating independently, could be construed as an alternative measure of such effects.

And since productivity was either the best or the second best of the variables tested in our individual firm regressions, we are not able to reject our second basis hypothesis, that managerial differences or motives may explain some of the differences in diffusion.

Nevertheless, the basic evidence in support of this second hypothesis is rather weaker than that in support of the first, which stresses direct economic effects such as rates of expansion, and factor price and market differentials. Perhaps the best overall summary of our analysis of diffusion of the basic oxygen process would be as follows:

(a) general market expansion seems to be the dominant influence;

(b) factor price effects also seem to be influential;

(c) some impact seems attributable to managerial or motivational differences;

(d) only an insignificant influence seems attributable to scale diffentials.

It should be observed, however, that in all of our analyses the unexplained residuals remain quite large. Much of what is unexplained may simply represent a good deal of measurement error and other extraneous influences, but the scale of these inexplained residuals is sufficiently large to suggest a very cautious interpretation of any findings or conclusions.[16]

Hence, from a strictly economic perspective, at least, the conditions under which the detailed disaggregation of the decisionmaking structure of the donor and recipient is necessary is unresolved.

NOTES

1. It is useful to distinguish between "diffusion in use, in which technology is purchased from the innovating country and used abroad....and transfer of production, where the foreign country has the capability to produce the innovation". Mathematica (1974, p. II-24).
2. Nabseth and Ray (1974, pp. 12-13).
3. Rudner (1966, p. 10).
4. Mansfield (1971, pp. 88-90).
5. Mansfield (1973, p. 208).
6. Mathematica (1974, p. II-25).
7. Williams (1973, p. 208).
8. Mansfield (1971, pp. 90-92), Rosenberg (1971, p. 310).
9. Mathematica (1974, pp. II-34, II-40).
10. Compare Gold et. al. (1970, p. 218) and Mansfield (1971, p. 95).
11. Nabseth and Ray (1974, pp. 297-298).
12. Sutton (1975, p. 273) and Gold et al (1970, p. 233).
13. Gold, et al. (1970, p. 233).
14. Ibid., p. 225.
15. Stoller (1966, pp. 12-14).
16. Gold et al. (1970, p. 223).
17. Meyer and Herregat in Nabseth and Ray (1974, pp. 192-195).

5. Substitution Analysis

A refinement of the preceding analysis of the diffusion of technological advances adopts the view of competitive substitution of one product, service, or process for another. It then follows that technological evolution consists mainly of substituting a new form of satisfaction for an old one. The end result to the user is the ability to perform an existing function or satisfy a current want differently than before.

A typical model of this process of competitive substitution is based on the following assumptions:

1. Many technological advances can be considered as competitive substitutions of one method of satisfying a want for another.
2. If a substitution has progressed as far as a few percent, it will proceed to completion.
3. The fractional rate of fractional substitution of new for old is proportional to the remaining amount of the old left to be substituted. 1

The rationale behind these assumptions is as follows. When a new method is first introduced, it is less well developed than the older method with which it is competing and it starts slowly as initial problems and resistance to the innovation are overcome. The substitution process proceeds more rapidly as the competition between the new and old technology grows more keen and the new technology gains an advantage and demonstrates economic viability. Finally, as the market for the new technology approaches saturation, the pace of substitution slows down. When the process is completed, the old technology may continue to retain some portion of the total market for which it may be particularly well adapted.

In forecasting the course and speed of the substitution process, the simplest approach is to project a function having the appropriate S-shaped curve using historical data to determine the free parameters.

For example, assume the rate at which the substitution process proceeds is given as $F/(1-F)=\exp k(T-T')$ where F is the fraction of the new product or service that has substituted at a time T, T' is the time when the substitution is half complete and k is a rate constant that can be defined in terms of the time, h, required for the substitute fraction, F=substitute/total to go from 0.1 to 0.9; that is, $k \doteq 2.0 \ln (9/h)$.

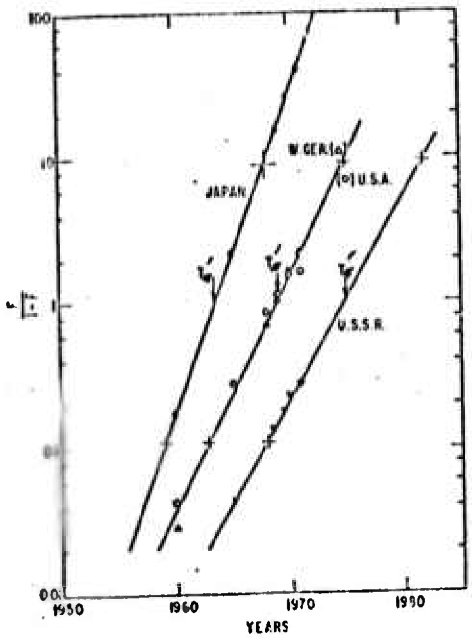
Thus, the total competitive substitution process can be characterized by two parameters: T', the substitution midpoint, and h, the time for the substitution to go from 10 percent to 90 percent.[2]

An example of the substitution of the basic oxygen furnace for the open hearth and Bessemer processes for making steel in Japan, West Germany, the Soviet Union and the United States is given in Figure 21.[3] Other major innovations in the United States iron and steel industry are included in Figure 22. While the substitution plots do not reveal the underlying causes for international differences in the acquisition and use of technology, they do, nonetheless, provide a means to identify trends and to suggest propositions that merit further study. How, for example, might one explain the significant time lag in the Soviet Union's use of the BOF process relative to other industrialized countries? Did a lack of first-hand knowledge of the technical operating characteristics of BOF plants delay the substitution for 5 to 10 years behind the others?

While nothing has been said about the effect of relative prices of the products or processes in question, the introduction of an additional assumption defining relative price movements over time will lead to the same general form of the logistic growth function above. More sophisticated variants of this simple substitution model are available and take into account the age, condition and rate of obsolescence of the capital equipment used in the old technology, an estimate of the time to perfect the new technology, time to train the users in the industry affected, and the price elasticity of demand for the final product.[4]

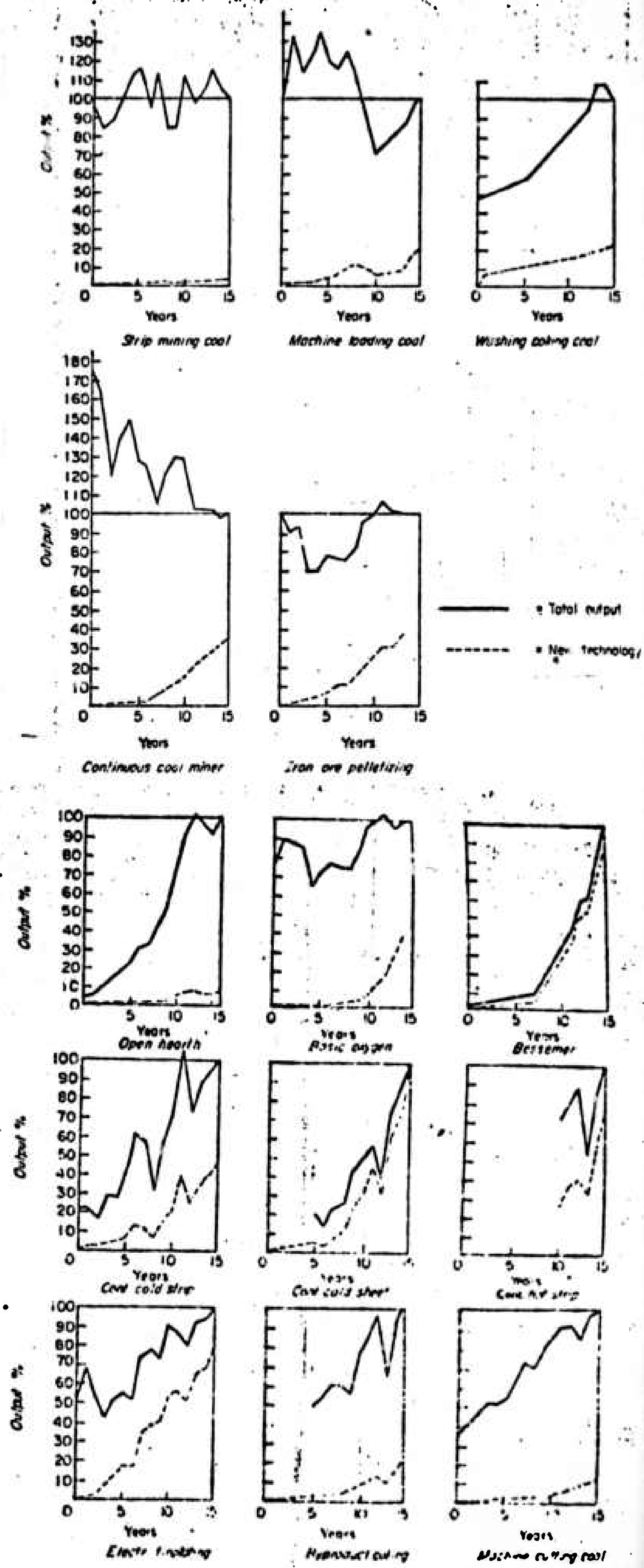
Figure 21 :

Substitution plot of BOF for open hearth and Bessemer steel production in Japan, U.S.S.R., West Germany, and U.S.A. since 1960.



Source: Pry (1973, p. 2).

Figure 22: Relative Contributions of 'old' and 'new' technologies to total output during first 15 years after commercial application of major innovations. (Total output in 15th year = 100.)



Source : Gold, et al. (1970, p.224).

NOTES

1. Fisher and Pry (1970, p. 1).

2. Pry (1973, p. 1-2).

3. Swan (1973, pp. 61-63) treats the substitution of synthetic for natural rubber in this fashion.

4. Stern, et.al. (1975) reviews and develops more detailed treatments of this process including models which allow for utility adjustment of the competiting products or processes based on market prices.

6. Spatial Analysis of Diffusion of Innovations

The work of Torsten Hägerstrand is another example of the analysis of the diffusion of innovations.

It combines an anthropological and geographical perspective as an approach to be taken in understanding social processes. William H. McNeil, in offering it as an alternative to the traditional organizing principle of European history as the ebb and flow of liberty, offers the following rationale:

> The basic notion is that of cultural pattern -- a cluster of repeatable forms of behavior that complement one another in mutually supportive ways and give definition and a limited predictability to aspects of human conduct caught up in and conforming to such a pattern.
>
> * * *
>
> Patterns of culture interact whenever men who share a given pattern of culture encounter strangers who do not share it. The strangers of course have their own set of culture patterns so that the encounter is an encounter of two different cultural patterns imprinted upon the partners to the encounter. In such cases mutual repulsion with no important change on either side is probably the commonest response. Sometimes, however, one or other partner to the encounter recognizes something attractive in the other's attainments, or something so formidable that steps must be taken to improve his own defenses lest some future collision bring disaster.
>
> Encounters of this sort, therefore, provoke men to alter, adjust, improve their particular cultural inheritance. Recombination of familiar elements to invent something new is one possibility. A second and far more common response to perceived deficiency in one's own cultural inheritance is to attempt to borrow and adjust whatever it was in the stranger's cultural accouterments that seemed superior. Through most of man's time on earth, human groups probably met strangers whose culture differed from their own within only a limited range. Hunters meeting hunters, and subsistence agriculturalists encountering subsistence agriculturalists were in a good position to appraise anything new in the stranger's repertory of skills and could borrow whatever seemed advantageous with little difficulty.
>
> But there are circumstances . . . in which strangers encounter one another as bearers of fundamentally different styles of life. In such cases, borrowing is more difficult. If it goes beyond trade for gewgaws and trifles, the effort to appropriate some strange new skill may create far-reaching conflicts between old and new cultural patterns. One change may lead to others, so that within a relatively short period of time the recipient society may find itself compelled to a kind of cultural mutation.

Across still wider cultural gaps, as when hunters and gatherers encounter civilized societies, not infrequently the upshot is disruption and dissolution of the weaker society.

* * *

Cultural patterns that are able to withstand comparison with those of strangers successfully tend to cluster at places where contacts among men of diverse cultural backgrounds are frequent. This is so because in such locations men have more choices thrust upon them; and having choices tend to prefer ways that seem in some sense superior to available alternatives.

These exposed locations were established through interactions between geographical layout and the technology of transport and communications. Geography channeled patterns of transport and communication toward certain nodes where culturally fertile encounters consequently became more frequent.

* * *

Places where men had maximal chance to choose the more effective, more impressive, more attractive way of doing things thus came into existence. The result was to create clusters of superior skill; and these clusters constituted the early centers of civilization.

As such centers defined themselves, complex and continuing interaction between civilized center and the barbarian fringes round about set in. Barbarian is here intended as a corollary of the term 'civilized.' Barbarians are peoples in touch with a civilized community, aware of the superiority of civilized accomplishments, yet also attached to their own different and distinctive way. Ambivalence results, mingling envy with disdain; but there is a persistent strain among barbarians to appropriate and make their own at least some aspects of the civilized cluster of skills as a way to improve their own lot and escape from a nagging sense of inferiority vis-à-vis their civilized contemporaries.

The upshot of such interaction was an outflow of culture traits from the civilized center to neighbors and neighbors' neighbors. Such flows sometimes traversed considerable distances when the borrowed item was easy to transport and could be smoothly insinuated into the receiving culture patterns of many differing peoples. In other cases geographical or cultural obstacles prevented the spread of a technique or idea for centuries despite proximity and ample opportunity for one community to learn from another.

The circumstances that lead to particular decisions to borrow or to accept an innovation generated by local reaction to alien contact vary greatly, and in most cases details are irrecoverable. Irrational as well as rational factors operate in human responses to novelty. All the same, acceptance of change is not wholly random nor is it uniformly distributed in time and space.

The processes whereby a new invention propagates itself within a society are almost identical with the processes whereby borrowed innovation resulting from contact with an alien society is propagated. Yet there is this difference. Men who accept and propagate a brand-new discovery or invention have the weight of tradition against them.

They are not spurred to act by fear or envy of some potent foreigner who seems superior in some important ways. Until recently, the result was inhibitory. If the innovation has not been thought of or needed by ancestors, most men judged that it could not be very valuable. With no outside threat to spur acceptance of change, conservative rejection was the normal reaction.

* * *

As a result, successful innovations tend to cluster in time and space. When this happens, what I propose to call a "metropolitan center" asserts itself. Such innovations by definition prove widely influential and acceptable to large numbers of people; this requires geographical spread from the locus of their initial emergence. When a number of such diffusion processes are simultaneously in train, what may be called a "cultural slope" arises, descending with varying gradients from the peak at the metropolitan center as one travels further and further away among peoples and communities where only some and eventually little or no trace of reaction to the achievements of the metropolitan center can be detected.

This is really no more than a metaphor, summing up millions and sometimes millions upon millions of individual reactions to personal experience. Moreover, the geological metaphor of peak and slope is imperfect, for in the same space-time quite different peaks and slopes may coexist, depending on what aspects of cultural behavior one thinks of. Thus, for instance, in Europe, 1650-1700, a map of metropolitan center and cultural slopes for music would differ sharply from that for physics; and still different patterns would exist for such things as mining technology, agricultural improvement, military organization, belles lettres, or for the writing and study of history. Moreover, during the last hundred years, when instantaneous communications have reached around the globe, a number of professional skills have arisen whose exercise is not closely tied to any single geographical center. Among experts like atomic-physicists or radio astronomers, reaction time to any important innovation, regardless of where it starts from is now very brief indeed.

In these conditions the metaphor of metropolitan center and cultural slope loses most of its relevance. But in earlier ages, when communications were much slower and resistance to innovation tended to be greater, there was a definite tendency for major innovation to flourish within quite limited geographical loci, and, characteristically, to persist for only limited periods of time.

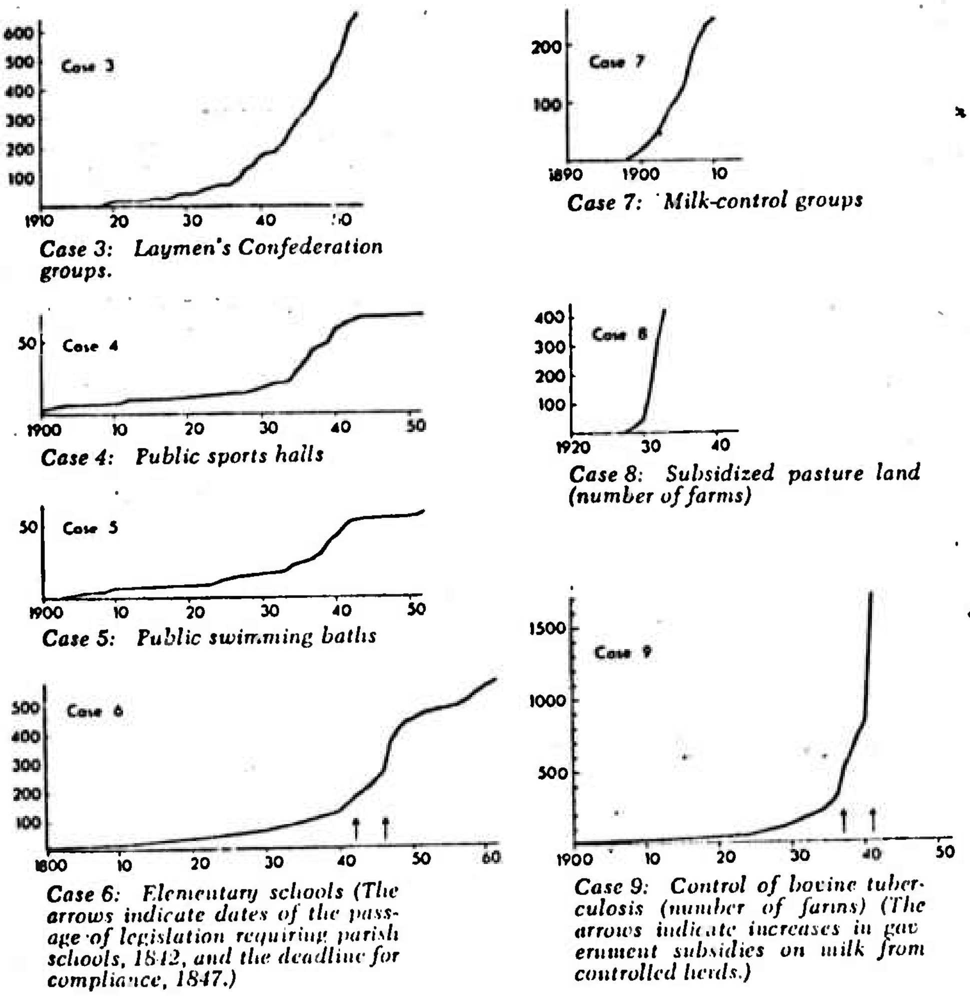
* * *

> I conclude, therefore, that through the larger part of recorded history the main drive wheel of historical change was contacts among strangers, causing men on both sides of such encounters to reconsider and in some cases to alter their familiar ways of behaving. Such contacts and the reactions to them generated civilizations. Within such civilizations, like a volcano in eruption, there arose specially active 'metropolitan centers' of innovation. The emergence of such centers in turn created cultural slopes. From time to time metropolitan centers shifted location, or a quite new center asserted itself; with such changes came changes in direction and velocity of cultural flows, that is, alterations in the alignment of cultural slopes. Such alterations, in turn, may be taken as defining major periods or eras of history. [1]

I cite McNeil at length for two reasons. First, these ideas are at the heart of the arguments of some of those who propose the creation of a "web of vested interests" between the U.S. and the Soviet Union as a means for keeping the peace, hastening convergence of the capitalist and communist systems, and facilitating the transformation of Soviet society, though they are not nearly as lucid in stating their case as is Professor McNeil.[2] (They also assume, as Leites points out, that the Politburo will have little say in the matter.[3])

Second, the work of Hägerstrand and others would indicate that, in the context of the diffusion of narrowly-defined, technical innovations at least, the idea of a "cultural slope" is more than just a metaphor.

> It is well known that the spread of innovations in society exhibits certain regularities. . . . Among them one will normally find trends which more or less closely follow an S-shaped curve (see Figure 23). Many attempts have been made to fit mathematical functions to such empirical findings in order to establish a "law of social growth".
>
> A complementary approach, the geographic mapping of culture-element distributions, has long been a standard procedure among anthropologists and cultural geographers. The purpose has been to establish 'culture areas' and 'cultural boundaries.' More stress has been laid on stability and tradition in space than on change over time -- and with good reason, for there exists a surprising amount of immobility in the picture. Change has been viewed as a displacement of culture boundaries between two widely separated points in time. Although the precision is notoriously low, a kind of 'law of geographical spread' has been ventured; it is said that innovations spread like ripples on water."[4]
>
> Ample material can be brought forward which shows that the demonstrated process is a typical one. A start is made by a rather concentrated cluster of adopters. This cluster expands step by step in such a way that the probability of new adoptions always seems to be higher among those who live near the earlier ones than among



Case 3: Laymen's Confederation groups.

Case 4: Public sports halls

Case 5: Public swimming baths

Case 6: Elementary schools (The arrows indicate dates of the passage of legislation requiring parish schools, 1842, and the deadline for compliance, 1847.)

Case 7: Milk-control groups

Case 8: Subsidized pasture land (number of farms)

Case 9: Control of bovine tuberculosis (number of farms) (The arrows indicate increases in government subsidies on milk from controlled herds.)

FIGURE 23: *Timing of the diffusion of new organizations and practices*

Source: Hägerstrand (1965, p. 245).

those who live further away. The potential adopters become 'blackened' with a spatial continuity reminding of the development of a photographic plate seen under the microscope. A convenient term for the phenomenon could be borrowed from this physical process: 'neighbourhood effect'."[5]

Nowadays the culture elements appear less and less frequently in mutually exclusive regions, as is essential if mere boundary lines are to give an adequate cartographic picture of their distribution. On the contrary, we will find all ranges of transition between centres where the element occurs in high density, and peripheric areas where it is rarely to be met with. When studying changes we cannot draw boundary lines and observe their displacements without very crude simplifications. Instead we must ascertain *the spatial distribution of ratios.* Changes in distribution are to be treated as changes of ratios and gradients.

Here the theory is maintained that changes in spatial distribution (i.e. changes in ratios and gradients) of culture elements occur in conformity to certain principles which are to be discovered.

* * *

The diffusion of an innovation propagates in two dimensions, the spatial and the social. We are going to examine only the spatial sides of the matter.

* * *

On the basis of the previous observations we may attempt to interpret the different types of changes.

Type I belongs to the *primary stage* of a diffusion process. Centres hastily grow up.

Type II brings a retardation in the primary centres. Instead there is a centrifugal increase in other areas trying to overtake these centres. New centres will appear. This is the proper *diffusion stage*, when the more considerable regional contrasts become levelled.

Type III is the *condensing stage.* The phenomenon in question is now commonly known.

Another characteristic feature too is a general retardation in the course of time. We have to suppose that the ratio surface asymptotical approaches a *saturation stage* when further increase is impossible in the given conditions. . . .

If we imagine the stages I, II and III passing in succession as on motion pictures, at the same time as the curve rises with retarding velocity, we will obtain some idea of the way *the innovation wave* propagates within a population. 6

An example of the application of these ideas to the diffusion of the automobile in Scania, the southernmost part of Sweden, from 1918 to 1930 is depicted in Figure 24 .

By comparing it with changes in the populated density for the region, Hägerstrand argues that "the urban hierarchy canalizes the course of diffusion".[7]

The concern here is less with the depth of that particular insight (Indeed, wherever people go, can their innovations be far behind?) and more with the method of analysis it suggests.

As mentioned before, the "conventional wisdom" on technology transfer asserts that it is a "people process". Hagerstrand's ideas and extensions of his earlier work provide an opportunity to test the hypothesis that there is a strong correlation between the mobility of certain people, whether they are called change agents, product champions, or gatekeepers and changes in the spatial distribution of technology.

In his later work, Hägerstrand, as have others before him, argued that there is a definite geographical structure associated with the diffusion of techniques and ideas through a network of social contacts. More importantly, it is hypothesized that this structure is

> rather stable, that is, the links connect different places with probabilities which presumably change only slowly and thus to some extent are predictable.

Hägerstrand attempted to test this thesis by constructing a Monte Carlo simulation of an innovation within a population.

> We start on a gaming table or "model plane" which is supposed to have (*a*) an entirely even population distribution and to be (*b*) an ideal transportation surface.
>
> "This isotropic model plane is divided into square cells which are supposed to be inhabited by the same number of individuals, N, in each. Every individual is a potential adopter of the hypothetical innovation.
>
> "The new element is spreading from one single individual living at the center of the model plane. In this process only face-to-face communication between pairs of individuals is considered. Newspapers, radio, television, books, public lectures and demonstrations are nonexistent in the model situation.

FIGURE 24: The Diffusion of the Automobile in Scania

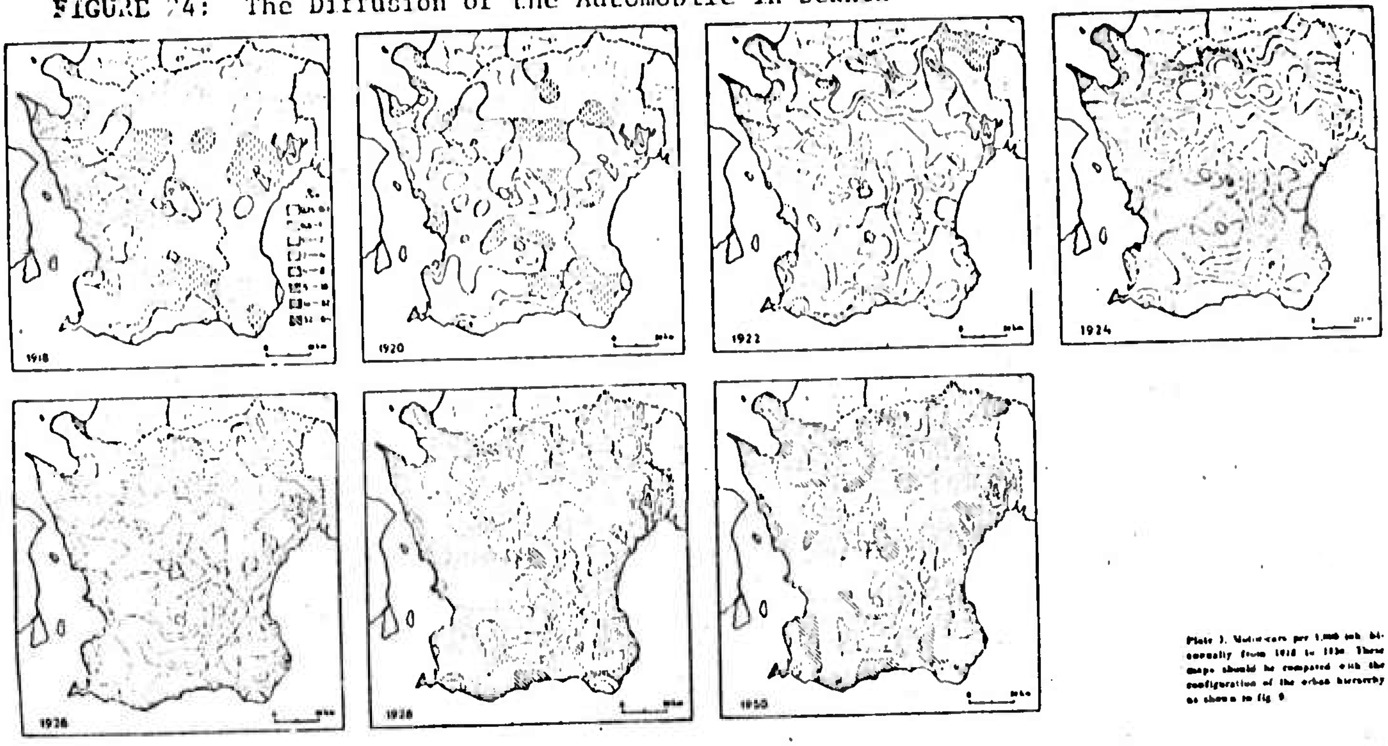
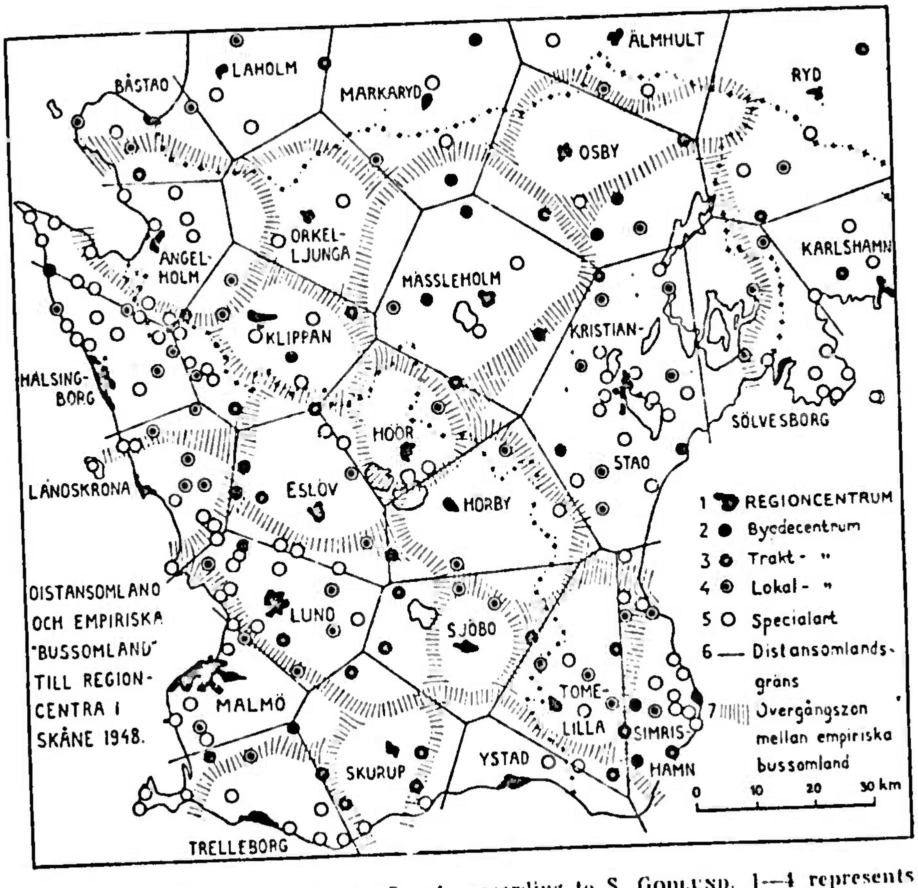


Plate 3. Motor-cars per 1,000 inh. biennially from 1918 to 1930. These maps should be compared with the configuration of the urban hierarchy as shown in fig. 9.

Source: Hagerstrand (1952, p. 21).



The urban hierarchy in Scania according to S. GODLUND. 1—4 represents centres in order of rank. 1. Regional centre. 2. Townlet centre. 3. Township centre. 4. Market centre. 5. Special urban settlement (e.g. industrial villages, fishing- and wateringplaces). 6. Distance hinterlands of regional centres. 7. The boundary zones of bus traffic hinterlands.

Among the regional centres Malmö (128,000 inh. 1930), Hälsingborg (56,000 inh. 1930) and Kristianstad (14,000 inh. 1930) possess a superior position.

The map is reprinted from GODLUND (1951).

Source: Hagerstrand (1952, p. 20).

The following rules are adopted as governing life in the model.

1 Only one person carries the item at the start.
2 The item is adopted at once when heard of.
3 Information is spread only by telling at pairwise meetings.
4 The telling takes place only at certain times with constant intervals (generation intervals) when *every* adopter tells one other person, adopter or non-adopter.
5 The probability of being paired with an adopter depends on the geographical distance between teller and receiver in a way determined by empirical estimate. [8]

Other versions include hypotheses concerning unevenly distributed "receptiveness" and "resistance" to the innovation in question.[9]

The relationship of Hägerstrand's work to the earlier discussion of the economic explanation of diffusion patterns based on profitably differentials is clearer

> . . . if we replace the term 'resistance' by something like a generalized 'readiness to assimilate,' which is the same thing with a change of sign, we see immediately that for investment decisions the 'profitability' measure becomes an index of resistance; it is an index of the extent to which a particular set of complementary or mutually supportive resources and attributes are present. [10]

Comparisons of simulated with empirical data for these more realistic versions have not, however, been carried to the point where the prognostic value of this approach can be ascertained.[11]

NOTES

1. McNeil (1974, pp. 24-43).

2. I do not mean by this that Professor McNeil also subscribes to this argument. I am unaware of Professor McNeil's position on these matters.

3. See Leites (1973, pp. vii, 12), Leonhard (1973, pp. 60-62, 67-73) and Lewin (1974, pp. 342-343) for discussion of the use of Western assistance as a substitute for Soviet economic reform and Leites (1973, pp. 37-41) for the shame about backwardness and dependence that is likely to afflict the barbarian in his encounters with these more civilized centers.

4. Hagerstrand (1965, pp. 244-245).

5. Hagerstrand (1965, pp. 46-47).

6. Hagerstrand (1952, pp. 3-4, pp. 16-18).

7. Ibid., p. 8.

8. Ibid., pp. 50-51.

9. Hagerstrand (1967, pp. 149, 263).

10. Anderson and Bowman (1965, p. 242).

11. Hagerstrand (1967, pp. 284, 285).

7. Multiple Criteria Decisionmaking

Economics has, in the main, concentrated on the macroeconomic impacts of technological change.[1] Among the more interesting (for the purpose at hand) examples in the microeconomic theory of the firm is an attempt to explain how technologically new products come into existence.[2] To my knowledge, it is the only presentation of technology transfer within the firm that treats the problem in this fashion.[3] Hence, it is quoted in some detail.

Technological change is defined as "a process by which a vector of characteristics is optimized".

The central explanatory device of this model depends upon the vector of physical characteristics associated with the products. Final products may be described by a vector of physical properties. If a set of minimally acceptable values for the characteristics have been specified, and if one or more of the specifications cannot be met, a bottleneck situation holds. The bottleneck may be removed either by a new material input or through a design change, i.e., a reconfiguaration of existing elements.

* * *

Let us assume that a firm produces a product that can be represented by a vector of characteristics or properties. That is,

$$Y = (y_i) \text{ where } i = 1, \ldots, n .$$

Given this vector of output characteristics, the firm proceeds to translate the specifications into a physical object. . . . In translating the specifications into a physical object, the firm acquires knowledge and skills that can be described as its technological base. This process of translating output specifications into physical reality adds to the firm's technological base in the following way.

Let us define a characteristic-technology transfer matrix:

$$A = (a_{i,j})$$

which is composed of zeros and ones as follows:

$$a_{i,j} = \begin{cases} 1, & \text{if achieving characteristic } i \text{ contributes to technology } j. \\ 0, & \text{if achieving characteristic } i \text{ does not contribute to technology } j. \end{cases}$$

For example, suppose the firm produces a product with characteristics m_1, m_2, m_3, which involve technologies T_1, T_2, T_3, T_4, as

$$m_1 \to T_1, T_2$$
$$m_2 \to T_2, T_3, T_4$$
$$m_3 \to T_1, T_3$$

	T_1	T_2	T_3	T_4
m_1	1	1	0	0
m_2	0	1	1	1
m_3	1	0	1	0.

An entry in the i^{th} row and j^{th} column denotes the contribution to the firm's knowledge of the j^{th} technology from achieving the i^{th} characteristic. Note that the sum of the i^{th} row is the number of technologies the i^{th} characteristic affects.

Let us now define a technology new product transfer matrix:

$$B = (b_{j,k})$$

composed of zeros and ones as[4]

$$b_{j,k} = \begin{cases} 1\,, & \text{if knowledge of technology } j \text{ is required to develop new product } k \\ 0\,, & \text{if a knowledge of technology } j \text{ is not required to develop new product } k\,. \end{cases}$$

For example, suppose the firm has knowledge of four technologies T_1, T_2, T_3, T_4 through the implementing of characteristics m_1, m_2, m_3 and these technologies contribute to the extension of the firm's product line to products P_1, P_2, P_3, as

$$T_1 \to P_1$$
$$T_2 \to P_2, P_3$$
$$T_3 \to P_1, P_3$$
$$T_4 \to P_1, P_2, P_3\,.$$

As above, we can define a transfer matrix B:

$$B = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}.$$

Element $b_{j,k}$ is interpreted as the contribution technology j makes to the introduction of new product k to the firm's line.

Note that the new product k is, itself, a vector of characteristics. It may have as elements some of the physical properties the achieved product (i.e., the current product or product line) possesses. It is an important point to emphasize that the characteristic-new product transfer matrix is not defined simply in terms of whether new product k possesses characteristic i. While the $C_{i,k}$ entry will be non-zero in such a circumstance, it is not necessarily true that $C_{i,k}$ will be zero if new product k does not possess characteristic i as an element.

The characteristic-new product contribution can be calculated as follows. Suppose achieving characteristic i adds to the firm's knowledge of technology j which is necessary to develop new product k. The complete link is

$$m_i \rightarrow T_j \rightarrow P_k$$

and can be calculated as

$$a_{ij}b_{jk} = 1 .$$

If the complete link does not exist,

$$a_{ij}b_{jk} = 0 .$$

The number of ways characteristic i contributes to new product m is

$$\sum_j a_{ij}b_{jk} .$$

If we let

$$c_{ik} = \sum_j a_{ij}b_{jk}$$

then c_{ik} is the number of ways m_i is contributing to P_k.

Let

$$C = (c_{ik})$$

then,

$$C = AB\,.$$

For example, we have

characteristics m_1, m_2, m_3

technologies T_1, T_2, T_3, T_4

new products P_1, P_2, P_3 .

Allowing A and B to be as in the previous examples,

$$AB = \underset{A}{\begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 \end{bmatrix}} \cdot \underset{B}{\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}} = \underset{C}{\begin{bmatrix} 1 & 1 & 1 \\ 2 & 2 & 3 \\ 2 & 0 & 1 \end{bmatrix}} = C\,.$$

We can interpret C as:

m_1 contributes to each product in one way;

m_2 contributes to P_1 and P_2 in two ways each and three ways to new product 3;

m_3 contributes two ways to P_1, no ways to P_2, and one way to P_3.

* * *

This analysis implies that there are products which are much more powerful in adding to a firm's (country's, individual's) technological base than would at first be suspected. The only change required in the analysis is to redefine m_i as existing product i instead of characteristic i .

The analysis also shows the linkages that exist between a new product and an existing one. It provides a rigorous framework within which to analyze the process of extension of the number of items in a firm's catalog. The only requirements are to be able to enumerate the characteristics of the existing product line, the technologies that have been developed through the attainment of the given product line, and the relative weights to be assigned to potential new products.

Empirical validation of this formulation, which has not occurred, is clearly in order , if only because of its similarity to the "ripple effect" caused by technical innovations.[4]

NOTES

1. Kennedy and Thirwall (1972, p. 62).

2. A more "traditional" treatment of technological change and the theory of the firm can be found in Becker (1971, pp. 124-134).

3. Perry (1973, p. 24-34) discusses the application of multivariate regression analysis to assess the relationship between technical quality parameters and performance parameters but not in the context of the effect of technology on the development of new product lines. Hirsch (1969) contains additional ideas that may prove relevant.

4. A case study of the "ripple effects" of technical innovations can be found in Peirce (1974, pp.43-51).

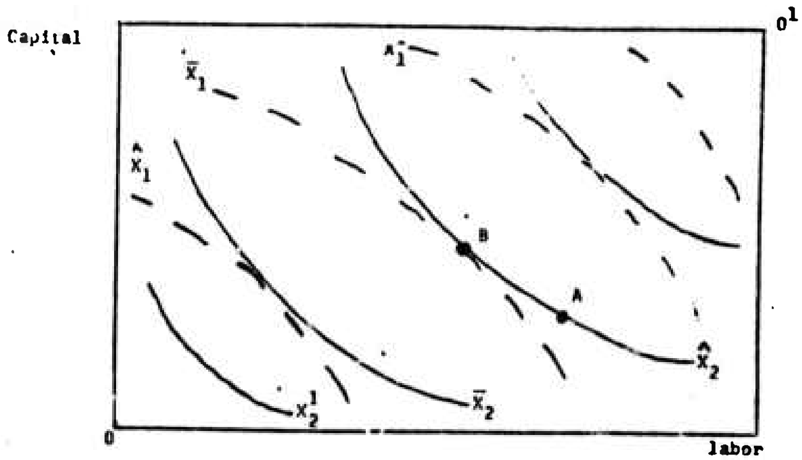
8. Edgeworth-Bowley Box Diagram

The issue of the "fungibility" of the resources released by East-West trade has been raised and thoroughly discussed by others.[1]

What is of interest in this regard is an attempt to apply the Edgeworth-Bowley box diagram for production to explain the effects of technology transfer to the Peruvian anchoveta fish and fish meal industry.[2]

> The allocation of capital and labor between the manufacturing and primary commodity producting sectors is readily exhibited in Figure 25 where two graphs have been combined into a box whose dimensions represent the amounts of capital and labor available to to our economy. A point within or on the boundary of the box represents a given allocation of capital and labor between the two sectors and a corresponding output of manufactured and primary commodities. Any point not outside the boundary is feasible in the sense that the output could be produced with the given supply of capital and labor. However, not all these points are "efficient." In many of these cases the combined output of the two commodities could be increased by reallocating resources. For example, A is sub-optimal since by reallocating resources to achieve B the production of X_1 is increased (since B is on a higher isoquant for X_1 than A). Points such as B represent economically efficient resource allocations since it is impossible to increase production of one commodity without reducing production of the other. Corresponding to each point on the technology frontier, there is an efficient allocation of capital and labor represented in Figure 25.

FIGURE 25: AN EDGEWORTH-BOWLEY BOX DIAGRAM FOR PRODUCTION



Source: Pontecorvo and Wilkinson (1974, p. 267).

To summarize, participation in a technology transfer program may shift the technology frontier . . . bringing about a new allocation of resources that involves a new composition of commodity output, a new distribution of resources between sectors of the economy, and related commodity and resource price changes. This in turn implies a new distribution of income, employment, geographical location of labor, etc. In more general terms, technology transfer, if it is economically significant, implies major changes in production functions, income distribution, and the location of economic activity. This in turn suggests the potential creation of new social, political, and economic order.

A moment's reflection will suggest the extent to which the development of the fishery and fish meal industry has had the effects indicated in the above paragraph on Peru. At the most general level the industry has focused the attention of Peruvians on the sea and its resources and, given the large and underexploited resources of Peruvian coastal waters, and has helped the further development of other fisheries. This assumption rests, in part, on the skills and capital that have been acquired in Peru as a result of the development of the anchoveta fish meal industry. We have no direct evidence on income distribution in Peru (approximately a quarter of the population is essentially outside the market economy). However, it is clear that the development of the fishery has created a set of skilled workers, boat captains, plant engineers, managers of various sorts, etc., with income levels well above national averages. A relatively capital intensive industry has been created with economic and political linkages that go beyond the borders of Peru and that require of Peru a new level of participation in international economic and political affairs as befits the leading fishing nation of the world. Internally, Peru has created a new set of production and investment opportunities. These range from fish catching and processing to boat building, manufacturing of ancillary equipment, the development of infrastructure (port installations, etc.) research on marine problems, etc.

Clearly then the development of this industry based on increasing world demand for the output and the convenient location of the resource has had a major impact on Peru. The transfer of this technology to Peru has changed production functions, probably significantly shifted income distribution, and certainly focused the attention of Peruvians on the ocean resources off their shores and shifted a significant amount of production from the interior to the coastal zone.

While the approach is more interpretive in its application, it can, nonetheless, suggest hypotheses for further research.

NOTES

1. Klitgaard (1974, pp. 27-35), Leites (1973, p. 6), and Wolf (1973, pp. 95-96). Schlesinger (1960, pp. 31-40) discusses the general resource allocation decisions confronting the Soviet leadership.

2. Intriligator (1971, pp. 260, 262), and Pontecorvo and Wilkinson (1974, pp. 266, 267).

9. Utility Theory

Klitgaard has used utility theory to give a formal structure to the problem of maximizing United States benefits from trade with potential adversaries.[1] He begins by defining a U.S. utility function in terms of the military power of the Soviet Union, the economic welfare of the U.S. and the political benefits to the U.S.

The military power of the Soviet Union is, in turn, related to the resource-saving gains and capability-enhancing gains which accrue to both the military and civilian sectors as a result of acquiring technology through trade. The various partial derivatives are used as a means of generating questions about export control policy and the optimal level of trade.

The analytical problems are, as he notes, estimating, in fact, how these variables change with the level and types of trade; optimizing multi-attributed utility functions; and implementing the resultant trade policy.[2]

NOTES

1. Klitgaard (1974, pp. 87-91).

2. Cochrane and Zeleny (1973) contains the most detailed survey of the problem of optimization with multiple objectives. Also see Huber (1974, pp. 445-453) for another review of the methods and models pertinent to multi-attributed utilities.

10. International Trade Theory

The implications of international trade theory for technology transfer have been recently reviewed by others.[1] The main contribution is from the 'technological gap' and 'product cycle' school of thought.[2] (See Table 16). Of particular interest is the work of M.V. Posner. He assumes that the basis of trade is the comparative advantage obtained by lags in the adoption of innovations by different countries.[3] Tilton explains the process as follows:

> (The) international diffusion of new technology involves two steps: intercountry transfer of the technology (either directly or embodied in imports) and intracountry diffusion. Four aspects of diffusion can thus be examined in assessing country performance in the acquistion of new technology. The first is the speed with which a country initially tries a new product or the demand lag. The second is how quickly the use of the product spreads amont consumers after introduction into the domestic market, as indicated by the growth in the country's consumption. The third is the speed with which the country acquires the production technology from abroad, or the imitation lag. The fourth is how quickly domestic producers adopt the technology once it is successfully transplanted into the country from abroad, as indicated by the growth in the country's output.[4]

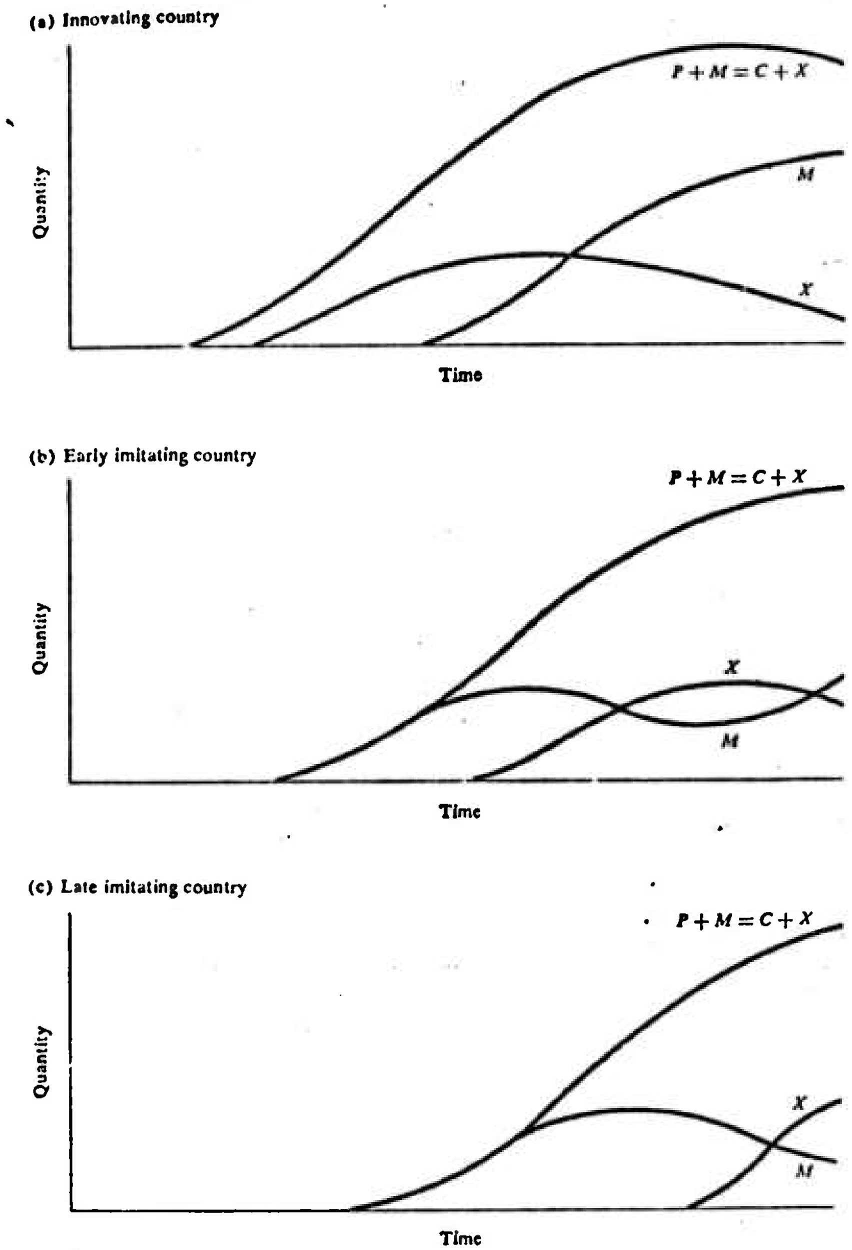
This phenomenon is depicted in Figure 25 and the theoretical effects of economic expansion, based on differences in technical progress, on the demand for imports is presented in Table 17 for two hypothetical countries, Mancunia and Agraria, in the case of incomplete specilization of production. In light of the empirical testing of this theory, its further application is warranted.[5]

TABLE 16: SYNOPSIS OF THEORIES OF INTERNATIONAL TRADE

Basic Composition of Trade Theory	Selected Proponents	Essential Commodity Characteristics	National Attributes Pertinent to Exports of Manufactured Goods
1. Factor proportions	Heckscher, Ohlin	Capital = labor ratios	Relative abundance of physical capital leads to export of capital-intensive goods; abundance of labor leads to export of labor-intensive goods.
2. Human skills	Leontief, Bhagwati, Kenen, Kravis, Keesing, Waehrer, Kenen-Yudin, Roskamp-McMeekin, Bharadwaj-Bhagwati, Lary	Skill requirements of production and distribution	Relative abundance of professional personnel and highly trained labor leads to export of skill-intensive goods; abundance of unskilled labor promotes export of goods requiring few skills.
3. Scale economy	Ohlin, Dreze, Hufbauer, Keesing	Extent of scale economies in production and distribution	Large home market is conducive to export of goods produced under increasing returns to scale; small home market is conducive to export of goods produced under constant returns to scale.
4. Stage of production	Import Substitution School	Economic "distance" from the final consumer	Sophistication abets producers' goods exports; simplicity abets consumer goods exports, especially "light" consumer goods.
5. Technological gap	Tucker, Kravis, Posner, Hufbauer, Douglass, Egendorf, Gruber-Mehta-Vernon, Keesing	Sequential national entry to production	Early manufacture of new goods confers an export advantage; later producers must rely on lower wages or other static features to promote exports.
6. Product cycle	Hirsch, Vernon, Wells, Stobaugh	Differentiation of commodities	Sophistication and early manufacture leads to export of differentiated goods; lack of sophistication leads to export of standardized goods.
7. Preference similarity	Linder	Similarity between imports, exports, and production for the home market.	Trade is most intensive between countries of highly similar economic structure, least intensive between countries of very different economic structure.

Source: Vernon (1970, pp. 147-148).

Figure 26 : DIFFUSION OF NEW TECHNOLOGY



a. The X curve shows the level of a country's exports of a new product (or product produced with a new process); the M curve its imports. The $P + M$ curve is the sum of domestic production and imports. It indicates the total amount of the product available to the country for domestic consumption and exports ($C + X$). The vertical distance between the $P + M$ curve and the M curve reflects the country's production and the vertical distance between the $C + X$ curve and the X curve its consumption.

Source: Tilton (1971, p. 21).

TABLE 17: SUMMARY OF EFFECTS OF EXPANSION

Type of Expansion	*Mancunia*			*Agraria*		
	Con-sumption	*Produc-tion*	*Net Effect*	*Con-sumption*	*Produc-tion*	*Net Effect*
I. *Technical Progress*						
(a) Classical case	I	UE	I or E, not UI	E	UI	UI
(b) *Equal rates*	I	N	I, possibly UI	E	N	E
II. *Capital Accumulation*	I	UE	I or E, not UI	E	UI	UI
III. *Population increase*						
(a) Slightly Diminishing Returns	E	UI	UI	I	UE	I or E, not UI
(b) Strongly Diminishing Returns	E	E not UE	E	I	I not UI	I, possibly UI

I = import-biased
E = export-biased
N = neutral
UI = ultra-import-biased
UE = ultra-export-biased

Source. Johnson (1955, p, 109).

NOTES

1. Johnson (1975), Vernon (1970), Kahn and Schneider (1974, pp. Cla-C5b), Boretsky (1974), Harmon (1974, pp. 15-18), and Tilton (1971, pp. 19-24).

2. Hufbauer in Vernon (1970, pp. 147-148).

3. Posner (1961, p. 324).

4. Tilton (1971, pp. 22-23).

5. Swan (1972), Ault (1974), Schott and Muller (1975).

11. Technology Transfer Functions

An alternative to the treatment of technology as a residual factor in a production function format is provided by a set of macro-economic estimating relationships called transfer of technology functions. These functions are of two types: impact functions and absorption functions. The first seeks to relate significant variables determining the output of goods related to the new technology that was borrowed from abroad. The second set is concerned with what explanatory variables facilitate a society's ability to absorb technology.[1]

The assumption is made that the transfer of technology cannot be measured directly, but is reflected in the movement of the following proxies selected as the dependent variables:

1. Total annual royalty remittances to foreign firms for licensing contracts and management (TCRp)
2. Technology balance of payments or net payments for licensing and management fees contracts (TCRn)
3. Import of technologically advanced machinery and equipment (MTmch), or import of engineering goods (MEng)
4. Dividends and interest paid on foreign capital investments (DI).

Four sets of factors have been advanced to which these variables are related and with which the impact and absorption functions are to be constructed:

1. General economic conditions
2. Level of the technological base
3. Exposure to foreign techniques
4. Availability of funds.

These four categories can be further decomposed into the set of independent variables identified in Table 18.

Regression equations can now be constructed and fitted to the data. When applied to the case study of Japan the functions took the following forms:

$$EJ_{te} = a + b_1 EW + b_2 Pic/Pj + b_3 TCR + b_4 MT_{rm} + b_5 MT_{mch-1} + b_6 RD + b_7 A \qquad (1)$$

$$SD_{te} = a + b_1 NY + b_2 CC + b_3 Mc + b_4 MT_{rm} + b_5 MT_{mch-1} + b_6 RD + b_7 TCR + b_8 I/L + b_9 LP \qquad (2)$$

$$TCR = a + b_1 NY + b_2 FX + b_3 MP + b_4 Dc + b_5 Re + b_6 Pa + b_7 RD_{-1} + b_8 A + b_9 Sch \qquad (3)$$

Table 18 :

GROUPING OF INDEPENDENT VARIABLES HYPOTHETICALLY RELATED TO TECHNOLOGICAL TRANSFER

General	Sources of Funds	Exposure	Technological Base
NY	IL	MP	Re
EW	RD	RD	RD
Pw/Pd	De	A	Sch
		MTrm	Pa
		MTmch	LP
			I/L
			Ete
			SDte

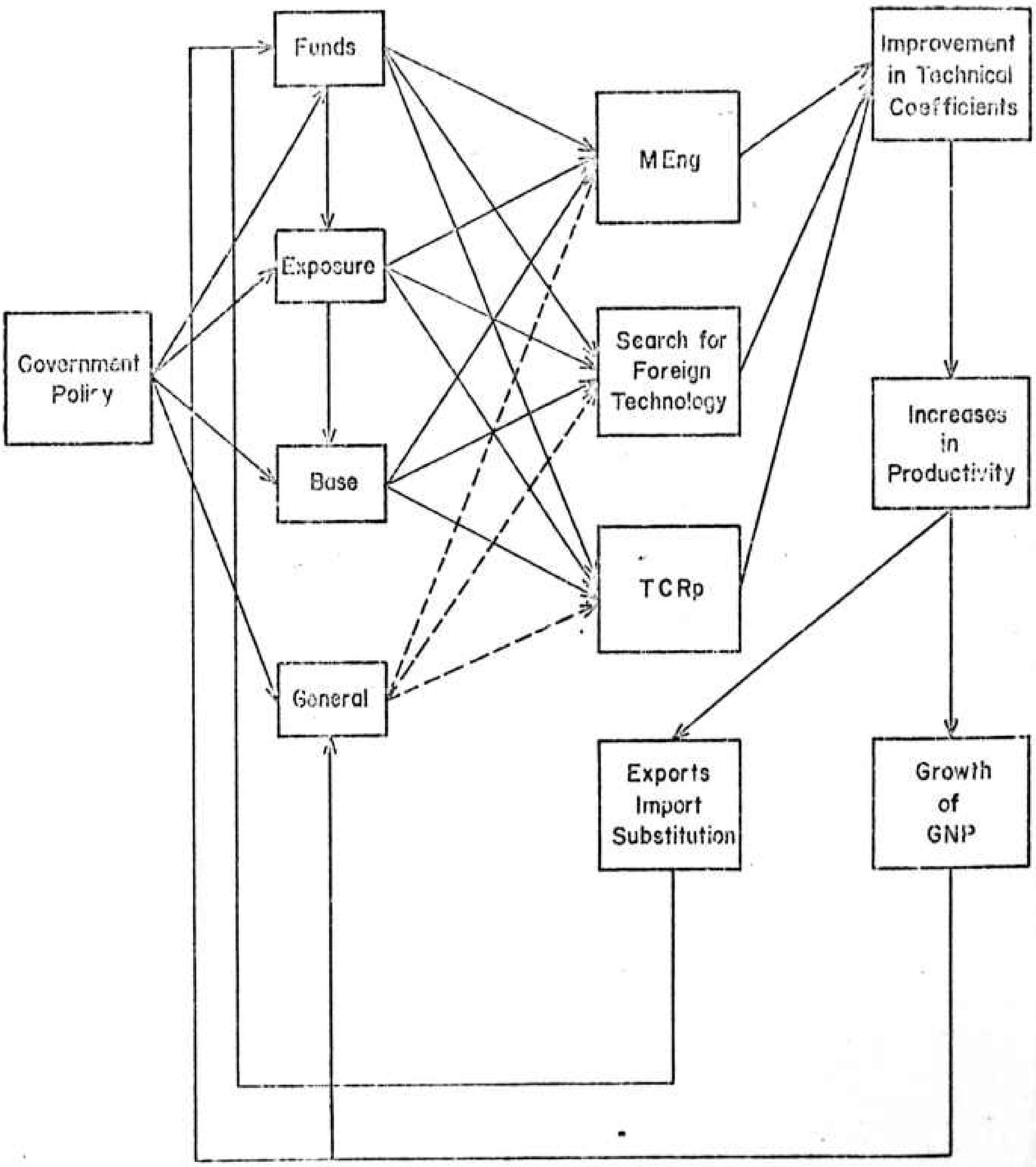
EXPLANATION OF SYMBOLS

1.	National Income	NY
2.	International Liquidity	IL
3.	Depreciation	De
4.	Patents registered	Pa
5.	Antennae	A
6.	Imports of technologically new machinery	MTmch
7.	Imports of engineering goods	MEng
8.	Imports of materials related to new technology	MTrm
9.	Royalty remittances and licensing fees to foreign firms	TCRp
10.	Royalty remittances and licensing fees received from foreign firms	TCRr
11.	Technological balance of payments (TCRp - TCRr)	TCRn
12.	Volume of technology transfer transactions (TCRp - TCRr)	TCRv
13.	Production of engineering goods for domestic market	PrEng
14.	Exports of engineering goods	XEng
15.	Domestic demand for engineering goods	DDEng
16.	Military Expenditures	MiE
17.	Number of researchers	Re
18.	Research and Development Expenditures	RD
19.	School Expenditures	Sch
20.	Dividends and Interest paid on foreign capital	Di
21.	World Exports	EW
22.	Ratio of two price indexes; Pw, World Manufacturing Export Price Index; Pd, National Manufacturing Export Price Index	Pw/Pd
23.	Military Procurements	MP
24.	Gross Domestic Investments (in private enterprises excluding residential construction) divided by total employment	I/L
25.	Exports related to new technology	Ete
26.	Domestic Sales related to new technology	SDte

Source: Spencer and Woroniak (1967, pp. 6,7, 9).

Figure 27 :

GENERALIZED FRAMEWORK
OF A TRANSFER MECHANISM



Source: Spencer and Woroniak (1967a, p. 48).

where the variables are identified by the following symbols:

1. *NY*, National Income in 100 millions of 1958 yen.
2. *FX*, Foreign Exchange Reserves in millions of 1958 dollars.
3. *MP*, Military Procurements in millions of 1955–7 dollars.
4. *De*, Depreciation in 100 millions of 1952 yen.
5. *RD*, Research and Development Expenditure in millions of 1952 yen (*R* and *D* is defined as expenditures by research institutes, universities and private companies in the field of natural sciences).
6. *Re*, Number of researchers in research institutes, universities, and private companies in the field of natural sciences.
7. *Pa*, Number of patents registered.
8. *Sch*, School expenditure (colleges and universities) in millions of 1958 yen.
9. *A*, Antennae—number of certain categories of non-immigrant aliens of Japanese birth admitted to the U.S. (namely, businessmen, industrial trainees, researchers, and other specialists)[2].
10. *CC*, Consumer Credit in million of 1960 yen (*CC* outstanding, excluding loans for repair and improvements of private dwellings).
11. *LP*, Labor productivity index.
12. *IL*, Gross Domestic Investment (in private enterprises excluding residential construction) divided by total employment, in thousands of yen per worker.
13. *TCR*, Total annual royalty remittances to foreign firms for borrowed technology in thousands of 1958 dollars.
14. *Mc*, Import of competing goods in millions of 1960 yen.
15. *SD*, Domestic Sales in 100 millions of 1955–7 yen.
16. MT_{raw}, Imports of Raw materials related to new technology in millions of 1960 yen.
17. MT_{mch}, Imports of machinery and producer's goods related to new technology in millions of 1960 yen.
18. *EW*, World Exports in millions of 1958 U.S. dollars.
19. *Pw/Pj*, Ratio of two exports price indices; *Pw*, World Manufacturing Export Price Index; *Pj*, Japanese Manufacturing Export Price Index.
20. EJ_{te}, Japanese exports related to new technology in millions of 1960 yen.
21. SD_{te}, Domestic Sales related to new technology in millions of 1955–7 yen.

The first two regressicns are impact functions set up to measure the relationship between Japanese sales, foreign and domestic, related to new technology and selected explanatory variables. The absorption function is represented by one proxy, TCR, the annual total payments made by the Japanese to the foreign supplier of technology.[3] The same approach has also been applied to data on West Germany. In fact, it has been hypothesized that the technology transfer process can be represented, in general terms, as a continuous, cumulative feedback process of the sort depicted in Figure 26 .

NOTES

1. Solo (1966, pp. 481-488), Moravcsik and Ziman (1975, pp. 599-724), and Rawski (1975, pp. 383-388), Wolf (1974, p. 24).

2. Spencer and Woroniak (1967a, p. 4).

3. Spencer and Woroniak (1967b, pp. 442-3).

12. Technology Transfer Index

The technology transfer index is an attempt to use a multidimensional scaling technique to subjectively assess the amount of technology transferred in non-monetary terms.[1]

> The first segment of the Technology Transfer Index outlined below is the product technology index, which describes products in technological terms. Unique rapidly evolving and complex products will receive high ratings but standard commodities will receive low ratings. The second index measures the production technology. Large-scale, highly developed production systems receive low ratings, but small-scale, evolving and flexible systems, receive high ratings. The third index measures the service which accompanies the product. The higher the service requirements, the higher the rating. The argument underlying these indices is that newer, or leading edge technology, is characterized by rapidly changing, poorly standardized products, comparitively less well developed production systems, and high service requirements. Their introduction into a new area indicates a fairly large quantum of technology transfer.
>
> The fourth index measures the state of technology in the host country area. If the state is relatively low, the net transfer will tend to be high for a given involvement. Low state of technology will be indicated by rapid growth in consumption, low rate of innovation, little local manufacture, and dominance by foreign firms.
>
> Respondents will be asked to rank technologies associated with specific product lines along these dimensions on a four-point scale. Criteria for judgement are provided. The scale, it should be noted, is a ratio scale. This, because people tend to think in terms of doubling or halving. The final number is obtained by multiplying values for each element rather than summing them, but in the present case the differences between the two computations is unlikely to be important. This approach has been extensively used for analysis of complex systems and it is possible to get a high degree of consistency and reproducability from different sets of observers.[2]

The results of the application of the index have not been reported as yet.[3]

NOTES

1. Press and Harman (1974, pp. 29-31), Foster (1974, p. 1).

2. Foster (1974, pp. 26-27).

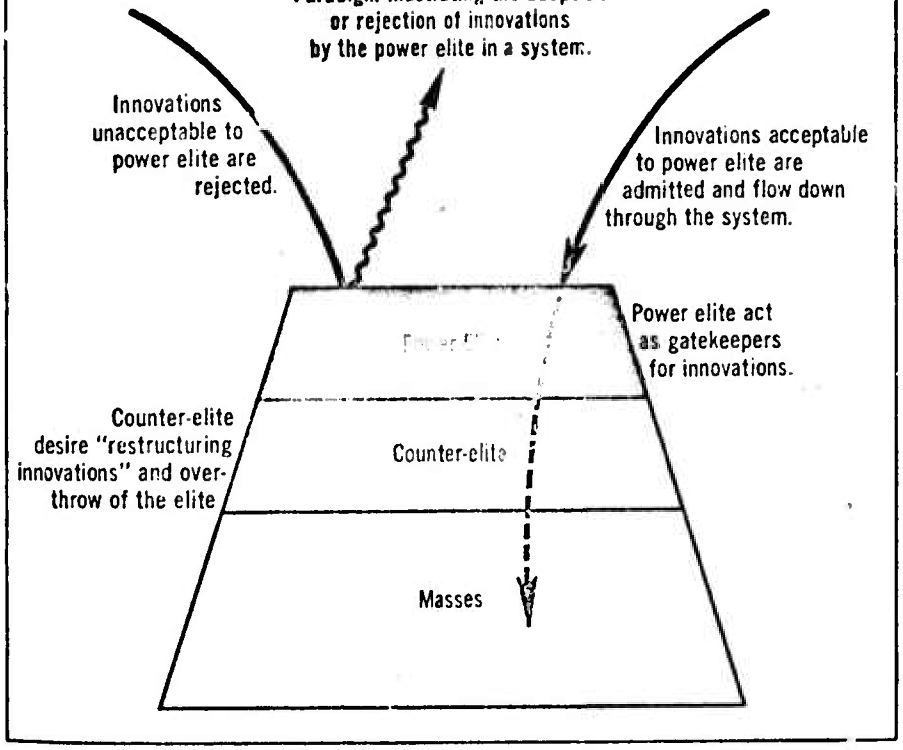
3. Nisenoff and Foster (1975).

VI. A Synthesis of Existing Methods

The effect of innovations, technical and otherwise, on organizational structure (and vice versa) has been noted by several authors.

> In any social system there is a hierarchy of social statuses. Those at the top, often called the power elite, are mainly responsible for making decisions affecting the entire system. Because of their position of power, the elite are able to act as gatekeepers in determining which innovations enter the system from external sources (see Figure 27).
>
> The elite are inclined to screen out innovations whose consequences threaten to disturb the status quo, for such disruption may lead to a loss of position for the elite. The "dangerous" innovations are often those of a restructuring nature, rather than new ideas which will affect only the functioning of the system.... Restructuring ideas are usually resisted by the elite.
>
> We conclude with (the following generalization): The power elite in a social system screen out potentially restructuring innovations while allowing the introduction of innovations which mainly affect the functioning of the system. There is so little empirical support for this generalization that it must be regarded mainly as an hypothesis for future study.
>
> Sometimes the masses, or at least the counter-elite (who are out of power and opposed to the elite), desire the restructuring innovations so much that they overthrow the elite. In a sense this disorganizing event illustrates that consequences can occur as the result of the original rejection of an innovation. We see, then, that the anticipated consequences of innovations can themselves cause consequences.[1]

Figure 28
Paradigm illustrating the adoption or rejection of innovations by the power elite in a system.



Source: Rogers and Shoemaker (1971, p. 341).

Whatever the motivation, realization of the opportunities inherent in the new technology (unless it represents only a small marginal improvement over previous technologies) will call for changes in social organizations, that is, in the ways in which people and institutions are organized to accomplish their purposes. (This will surprise no one who has had the experience of learning the way to handle a new tool previously unavailable to him). Such new organizations do not spring from nothing, however. They grow up alongside, or they replace, previously existing social structures, which are themselves organized to use earlier technologies in the achievement of previously defined goals. To the extent that the new organizations compete effectively with the older ones for economic resources and political status, the goals served by the older structures may be less adequately achieved than they once were. The gain realized by achievement of new goals, in other words, involves some loss in the realization of older goals, and it is the same technological/social process that brings about both the gain and the loss.[2]

What decides the direction in which technology is applied, therefore, is the dialectical process of political competition. Instead of a cumulative process of adaptation to technology, politics reflects the swing back and forth of different group interests using technology to resolve issues of authority and relative influence.

* * *

> Historically, then, dominant groups have developed technology to serve their social aspirations. Eventually, these groups felt their own principles of social improvement deserved wider application.[3]

Nor should it come as a surprise that the little evidence which can be marshalled in support of this position is based on the study of the effects of the presuppositions and perceived needs (previously referred to as political myths) held by these dominant groups on lags in the adoption of innovations by the military or paramilitary organizations of which they are a part.[4]

The need to consider the political and organizational context confronting technical innovations is especially appropriate in the case of the Soviet Union where, true to the Hegelian dialectic, the tension between "Red" and "Expert" gives rise to the "Red Expert".[5] These are the kind of facts which must be brought to bear in operationally defining 'bureaucratic resistance' and 'organizational response' in examining the reality of resource fungibility in the Soviet context.[6]

What is lacking is a systematic procedure for incorporating these insights. At present, the only promising method for doing so is based on a synthesis of case study aggregation techniques, abstract descriptions of the technology transfer process and the organizational process and bureaucratic politics models of Allison, Halperin and Marshall.[7] This means identifying "the relevant Soviet organizations involved in the sequence of decisions and in the processes of carrying out" the development and use of particular technical innovations; displaying "the patterns of organizational behavior from which the action probably emerged"; and predicting "the organizations likely to be involved in future decisions and program actions and the routine patterns of these organizations" in order to "produce forecasts of likely (technical) developments".[8]

Figures 28 and 29 are the equivalents of the organizational process model applied to the problem of technology transfer in the Soviet Union. In its simplest form this means determining whether an organization is or isn't involved in the technology transfer process treated by the case study and the nature of its involvement. In the latter case, Bar-Zakay's abstract description of the stages in the transfer process is the analytical framework used as a first-order refinement of the meaning of organizational participation.[9] These organizational patterns for particular cases and, conversely, the case patterns for particular organizations can then be traced. Subsequent refinements would explore other analytical frameworks and case variables, such as the decisionmaking and communications structure for the organizations involved, including the identifica-

Figure 28: THE PATTERNS OF ORGANIZATIONAL INVOLVEMENT IN THE TRANSFER OF TECHNOLOGY

CASE STUDY VARIABLE OF INTEREST = ORGANIZATIONS / CASE STUDIES AVAILABLE	ORGANIZATION NO. 1	...	STATE COMMITTEE FOR SCIENCE AND TECHNOLOGY	..	ORGANIZATION NO."N"
CASE STUDY NO. 1					
⋮					
CASE STUDY NO."I"			(YES,NO)		
⋮					
CASE STUDY NO."M"					

FIGURE 29: THE EXTENT OF ORGANIZATIONAL PARTICIPATION IN THE TECHNOLOGY TRANSFER PROCESS

ANALYTICAL FRAMEWORK = BAR-ZAKAY'S MODEL OF TECHNOLOGY TRANSFER / CASE STUDY VARIABLE = ORGANIZATION	STAGE OF THE TECHNOLOGY TRANSFER PROCESS			
	SEARCH	ADAPTION	IMPLEMENTATION	MAINTENANCE
ORGANIZATION NO. 1				
⋮				
STATE COMMITTEE FOR SCIENCE AND TECHNOLOGY			(YES,NO)	
⋮				
ORGANIZATION NO."M"				

tion of gatekeepers, product champions and change agents and their importance in individual instances of the transfer of technology. This procedure could then be varied, in parametric fashion, over the kind of technology and type of transfer process involved and the resulting patterns compared and contrasted.

The development of this approach is intended to result in an inventory of propositions of varying credibility, accompanied by evidence either for their support or refutation, which address themselves to particular technology transfer issues and to which the policymaker can turn for assistance in answering his questions.

Given the changing nature of the Soviet Union's organizational structure under conditions of economic reform, any inventory of propositions will need to be periodically reviewed and updated with follow-on cases. This will, of course, be true of any method which focuses on organizational structure as an explanatory variable in the technology transfer process. The method just described, however, has the benefit of demonstrated feasibility and a backlog of propositions, analytical frameworks and case studies on which to build.[10]

NOTES

1. Rogers and Shoemaker (1971, pp. 340-341).
2. Mesthene (1970, pp. 28-29).
3. Nau (1974, pp. 25, 30).
4. Schlesinger (1974, pp. 87-88; 1968, p. 5), Lofgren (1971), Perry (1967), Katzenbach (1958), Liddell-Hart (1966), De Gregori and Pi-Sunyer (1966), Art (1973), Kelly (1970), Allison and Morris (1973), Archibald and Hoffman (1969), Hewlett and Duncan (1973), Steinbrunner and Carter (1975).
5. Campbell and Marer (1974, p. 5) and Bailes (1974). Additional commentary on the conflict between elite groups in the Soviet Union, especially as it relates to technology, can be found in Leonhard (1973), Lewin (1974), Odum (1975), Holloway (1971, 1974), Lieberstein (1975), Garthoff (1975), Aspaturian (1972), Lee (1972), Gallagher and Spielmann (1972) and Kolkowicz (1964).
6. See Schlesinger (1960, pp. 31-40; 1967, pp. 85-90) and Klitgaard (1974, pp. 29-30) for elaboration.
7. Allison (1971), Halperin (1974) and Marshall (1971). This synthesis is discussed in greater detail in Kozemchak (1975b).
8. Marshall (1971, p.1).
9. Bar-Zakay (1970).
10. Farrar (1975)

VII. CONCLUSIONS

The state of the art in the analysis of the international transfer of technology is such that this field of inquiry is not of direct and immediate assistance in answering policymakers' questions. The literature is, nevertheless, a valuable source of guidance on the design of methods of analysis which offer a greater chance of success in accomplishing the objectives set out in the preface to this report than might otherwise be the case.

Given the current state of the art, a case study approach is the preferred method analysis. In particular, in order to take advantage of existing research and increase its relevance for policymakers, a comparative study of the development and diffusion of technical innovations in the U.S. and Soviet Union, which has as its objectives the development of a propositional inventory and the validation of a method of analysis based on a synthesis of organizational process models, abstract descriptions of the technology transfer process and case survey techniques, should be undertaken.

APPENDIX A

THE ANALYSIS OF THE INTERNATIONAL TRANSFER OF TECHNOLOGY:
COMMENTS ON THE STATE-OF-THE-ART

(The following sample of published assessments of the state-of-the-art by researchers in this field, differences in the particular policy question of interest notwithstanding, is intended to augment the evaluations given in the body of the report.)

1. "It is somewhat difficult to formulate a discussion of the state of the art for analyzing the causes and effects of technology transfers. I have suggested that the transfer of technology is seldom an isolated activity, occurring independently of some other transaction. Thus the problem is not so much with the adequacy of our research methods as with the clarity of thought being given to formulation of questions for investigation.

***

Because (of) the paucity of clearly framed questions about international technology transfers, per se, it is difficult to discuss intelligently the data and concepts needed to answer them.

Regarding analytical models and concepts, I can only protest that many of those used to investigate technology transfers and related matters are highly myopic and potentially deceptive in their policy conclusions.

***

Given the negative conclusions about the meaningful character of questions about technology transfer and the inadequacy of the relevant information, it is clear that I have little to say about the relevant policy options." (Emphasis added.)

Richard E. Caves, July 1974

2. "The consensus was that there is justification for the view that anyone seeking expert advice on East-West trade and technology transfer -- student, scholar or decisionmaker -- often cannot draw upon firm knowledge but is confronted with a wide spectrum of informed opinion whose scientific base is not always well established and whose action implications cannot be clearly drawn. To some degree, of course, such uncertainty follows inevitably from the nature and complexities of the subject matter. But even so, one of the main conclusions emerging from the conference was that there is a strong need for a better definition of the issues, and for a more carefully analyzed and integrated knowledge base to understand the forces, prospects, and implications of increased East-West commercial contacts." (Emphasis added.)

Robert W. Campbell and Paul Marer, May 1974

3. "The 'research' is currently diverse, loose, full of gaps and contradictions.... Much of the disorder is due to lack of standard or even fully-disclosed methodology for conducting studies, collecting data, and making inferences from the findings (despite the complex trappings of statistical tests and analytical methods)."

Charles F. Douds and Albert H. Rubenstein, June 1974

4. "Any attempt to assess the impact on international transfers of technology runs into two important problems. We have not agreed on a definition of technology and we do not know how to measure the amount transferred...

Thus, we are left with the conclusion that we really do not have a good approximation of the value of technology leaving and entering the United States and, in fact, we know relatively little about technology transfer.

I have come to the conclusion that, at the present time, we do not have sufficient knowledge to change existing national policy on technology transfer." (Emphasis added.)

Robert B. Stobaugh, July 1974

5. "The literature in this field contains many words of wisdom, insights and inspirations for the individual. However, among this plethora, there also exist many platitudes, vague generalizations, enigmas, and contradictory implications as one compares one document with another.

The situation, at least with respect to volume, is somewhat different when one inquires of this literature as to its empirically based findings. When interest is restricted to science-based research on the relations between science and technology, technological development, and the introduction of new technology into the production process, it is in this sense that the literature becomes quite small."

Charles F. Douds, 1971

6. "...(There) are relatively few case studies specifically of international technology transfer, and all but a very few of the significant ones omit consideration of the organizational and behavioral factors involved in the transfer process." (Emphasis added.)

B.M. Kohler, A.H. Rubenstein, C.F. Douds, 1973

7. "There has been little progress toward building the bridges between theory and practice (scholars and managers) which are needed for testing and evaluating the research and for the subsequent improvement of the practice."

Marvin J. Cetron, 1974

8. "...(There) seems to be little hard evidence to confirm or reject the various opposing views about the general political consequences of expanding East-West economic relationships and relaxing export controls. Each of us remains his own expert on the matter of political gains. In particular diplomatic and negotiating contexts, however, the case for expecting such gains may be stronger than it is as a general proposition."

Charles Wolf, August 1974

9. "...(The) thesis that there is (or has been) a net penalty incurred by countries which have been innovators... has never been properly proved, nor even adequately formulated. (It) continues to be stated as a self-evident truth."

Edward Ames and Nathan Rosenberg, March 1963

10. "...(Discussion) of the transfer of technology usually shows little recognition of what general-equilibrium international trade theory tells us about the transfer of technology in its pure form. These models do not easily yield operational research designs, but they do provide a framework that is highly useful for exposing the gaps in more partial approaches."

Richard E. Caves, July 1974

11. "One of the first questions involves our lack of understanding and knowledge of the relationship between research and development (really the development of new technology), and the diffusion of this technology internationally and domestically. Specifically, we don't have a very good understanding of how any level or type of R&D gets translated in terms of diffusion within the economy and internationally. Also, we don't know about the effects of international and domestic diffusion on R&D activities.

The second question which came up was that we really don't know anything, and this is rather surprising, about the market for licenses....

The third question that came up is, what are the differences in the diffusion of technology associated with the different channels, that is exports, foreign direct investment and licensing? And many of the policy considerations really focus on controlling one or two of these channels -- foreign direct investment and licensing. They don't discuss other channels like exports, the diffusion of information publication, or communication among individuals.

And finally, the question came up that we don't know very much about the difference of earnings -- and earnings can be interpreted fairly broadly from a social point of view -- from different forms of exporting technology. The question of earnings includes factors of production in the society, and for consumers as well, for the different channels of technology transfer. We have almost no information about that. Such information is obviously quite important in order to make any kind of policy judgments. ...(It) turns out that most of the discussion, at least from my impression, tended to focus very much around our ignorance about the four sets of questions." (Emphasis added.)

Rolf Piekarz, July 1974

12. "Far too little is known about historical experience in these policy areas. Further historical research in this field, difficult though it is, could prove most valuable. Additionally, much value could come from country-based evaluation studies. It is all too clear...that too little is as yet known about the spread of new technology, about its impact upon rural producers, and about past and likely future secondary effects on the rest of the economy. This is all the more lamentable in view of the hopes that rest upon the new technology. The consequences of the success or failure of the new technology are too critical for the present imperfect state of our knowledge about it to be acceptable."

R.T. Shand, 1973

13. "Because of the complexity of this process, and the fact that it has received relatively little attention in the past, our knowledge of it is still rather meager, particularly when compared with the demand for information by policymakers facing questions related to this process.

***

All in all, both the benefits and the costs to the United States of increases in technology transfer seem remarkably hazy."

Edwin Mansfield, May 1975

14. "In conclusion, it is important to recognize that economists are only beginning to study technology transfer in a serious way and that far more research is needed. We know far too little about the nature of the transfer process, the determinants of its costs, and the relative efficiency of various kinds of transfer techniques. We also know far too little about the effect of technology transfer on trade patterns and economic growth. However, I do think that economists are far more aware of the importance of technology transfer than they were 10 or 20 years ago, and that the chances are good that we'll know a lot more about these matters in another 5 or 10 years."

Edwin Mansfield, January 1974

APPENDIX B

THE INTERNATIONAL TRANSFER OF TECHNOLOGY: "PREFERRED" METHODS OF ANALYSIS

(The following sample of published recommendations for further research is intended to give the reader a feeling for the "preferred" methods of analysis that have been suggested in conjunction with the investigation of particular questions associated with the various policy issues. It is not an inventory of research questions of interest. Such a compilation, however, can be gleaned from the corresponding source material.)

1. "...(There) is a great deal to be gained, I would think, by doing a number of...case studies and then trying to put them together, any single one of which may be rather difficult to interpret. I would think that it is the cross-case study links that are important.

***

What are some studies that might be made? First, studies are badly needed of decisionmaking costs and efficiency of technology transfer. We know very little about them. More case studies are needed. Why did firms transfer what they did when they did, in the way that they did? How costly is technology transfer? How does it vary with the technology, the transmitting organization, the receiving organization, and the way the message is sent? All these questions must be important, but we do not really have any hard information with which to answer. Yet I think that some could be obtained. I do not see any reason why it could not be.

What sort of adaptation of process or product did the transfer agent make in each of these cases, as well? I think this is a controversial question, particularly so far as the less-developed countries are concerned. It would be interesting to know a little bit more about what, in fact, has gone on.

Next, studies are needed of the rate of international diffusion of innovation. Data are needed for more products concerning the imitation lags, data like Huffbauer's and Tilton's and so on. There is no reason why simple models could not be used, just in the way that they have been within a country, to look at diffusion. I am not saying that they can be, I am just saying that I do not see any reason why they cannot be used in this way. Certainly, some attempt should be made to find out." (Emphasis added.)

Edwin Mansfield, June 1973

2. "...(The) effectiveness of technological transfer must be studied in the context of the organizational and management system of the borrowing country and the political-cultural environment in which it operates. The centrally planned economies (CPEs) present many problems to innovation and diffusion of

domestic technology that probably also affect the successful absorption of foreign technology.

To understand the potential impact of borrowed technology on CPEs, it is important to focus not only on the general strengths and weaknesses of the innovation process in CPEs but also on specific variables influencing the successful absorption of imported technology. Some of the variables suggested are: (1) differences in factor proportions in the buyers and seller in the given industry (developing measures of relative technological levels is itself an important contribution); (2) how dynamic technological change is in the relevant industry and at what point in this evolution technology is being transferred by the exporting country; (3) at what stage in the development of an industry in the importing technology is being purchased from abroad; (4) whether technology is being accompanied by the seller's equity and management, or more broadly, the strength of the seller's incentive in the successful adaptation by the buyer.

The case study method might be particularly useful in approaching these problems, provided the cases are chosen to provide useful generalizations. Better knowledge of the purpose in importing technology would help in choosing appropriate case studies and the criteria to evaluate them." (Emphasis added.)

Robert W. Campbell and Paul Marer, May 1974

3. "In trying to assess how technological borrowing from abroad works in the Soviet system, one approach would be to do case studies of particular areas of technology where the Russians have already made serious efforts to import technology, such as in chemicals. In addition to the usual kind of research based on Soviet sources, it ought to be possible to get some idea of the experience of the firms that have supplied chemical plants, training assistance, and licenses in this area. The case studies should be chosen with a view ultimately to generate valid generalizations by applying some model to find what variations account for differences in performance.

Another approach would be to focus on an industry and study the state of its current technology relative to world standards, and investigate what obstacles have prevented its catching up with the technology of advanced nations and how borrowing in the past may or may not have been effective in catching up in certain aspects of its technology. Intensive study for particular industry makes it possible to develop a detailed picture of its decisionmaking process for technological policy, of the habits of thought and biases of its officials, and of its network of R&D institutions....

It is clear that there is no unique institutional pattern or set of rules for success in technological borrowing, just as there is no single set of institutional prerequisites for overcoming the obstacles to industrialization. Other cases, such as the experience of Japan or of multi-national corporations, suggest useful questions to ask and hypotheses to be investigated concerning the technology borrowing by the socialist countries, but we should not conclude that the Japanese have found the key and the Russians will be more or less successful depending on how closely they follow the Japanese pattern. Also there is enough variety in the success of Soviet borrowing -- among industries and between historical periods -- to alert us to the importance of existing technical level in the industry in question, variations in institutional and policy obstacles among cases, and the interaction of the receiving environment with the specific demands of a particular candidate technology for transfer.

Perhaps the first requirement for an understanding of transfer potentials is careful examination of a large number of cases of borrowing -- successful or ineffective, historical and current -- to illuminate the variety of factors that are important in influencing success and failure. Once that is done, it might be possible to employ on the results more elaborate statistical approaches that could distinguish what factors seem to be dominant in transfer success and thus permit sound generalizations. That implies that the people who do the case studies should make an effort to produce as part of their studies the kind of quantitative information that the subsequent testing of hypotheses would require." (Emphasis added.)

Robert W. Campbell, May 1974

4. "(1) Of potential value in understanding the present and future processes of technology transfer to the Soviet Union would be an in-depth study of the historical experience, i.e., the international transfer of technology in both the Sovet period in the 1920s and early 1930s and in the pre-revolutionary period. This is especially so in regard to the pre-revolutionary experience. The transfer of foreign technology to Russia in the period 1890-1914 by companies involved in direct investment in Russia was quite extensive, and judging by some of the studies of this experience, quite successful. Further work on the historical record should throw interesting light on the current situation.

(2) Another useful approach might be to do a number of industry production function studies within the Soviet economy, say, a dozen or more, covering the postwar period. From these studies, rates of change in the residual would be derived. These rates of change might be cleansed for such non-technical-change factors as economies of scale, etc. Then the rate of change of the residual (representing the rate of technical change) would be treated as the dependent variable in a cross-section repression study. The independent variables to explain the variance in the dependent variable would be the various hypothesized factors that contribute to the rate of technical change, for example, the rate of growth of output, expenditures on R&D, etc.

(3) It might also be advisable to undertake an extensive survey of the experience of the last ten years of American and other Western and Japanese companies in transferring technology to the Soviet Union and Eastern Europe.

(4) It might be possible to undertake industry by industry studies within socialist countries, follow the steps outlined under (2), and try to explain differences in the rate of technical change.

(5) Finally, it may be feasible to identify major innovations in the USSR in a given sector, or several sectors, by involving the specialists in the industry and then trace the path of these innovations in the West and compare them with the Soviet case." (Emphasis added.)

Herbert Levine, May 1974

5. "...(As) Posner and Hufbauer...have pointed out (though in neither case with enough specificity to clarify the nature of the problem) there is a need for more fundamental analysis of the welfare effects of technological leadership and their diffusion, and correspondingly of the economics of government intervention in these matters."

Harry G. Johnson, 1970

6. "Market for licenses. One of the areas of our greatest ignorance is surely the market for the licensing of technology... I do not see any way to evaluate this market for licenses except through close study of the buyers, sellers, and terms of the bargain struck.

Channels of technology receipt. To what degree can the various channels for the transfer of technology be substituted for one another? We have plenty of casual evidence on this question, but it is capable of systematic investigation. One attractive design would be to compare a given industry in several countries that are not important originators of technology and that have apparently used different channels to ingest it. For example, Japan blocks most direct investment and encourages licensing; other countries vary sharply in the restraints they place on trade relative to direct investment. Because "technology" is not an easily measured flow, I suspect that only a painstaking analysis of cases would be feasible.

Domestic and international diffusion of technology. Substantial studies have been made of the diffusion of innovations within U.S. industries and of diffusion across national boundaries, but I am unaware of any attempt to compare intranational and international diffusion rates within a given industry in relation to the channels through which they operate. In context of such an investigation, it should be noted that the sources of innovation are often multinational, so that confining the inquiry to innovations arising in a single country could lead to deceptive results.

Technology transfer and direct investment. Most of our knowledge about transfers of technology through the multinational firm is anecdotal and incomplete. What has been the experience of foreign subsidiaries of U.S. firms with the successful imitation of their technologies by foreign competitors? To what extent have subsidiaries generated or acquired technologies for transmission back to their American parents, and on what terms have these technologies been acquired? How soon are new U.S. technologies of the parent employed in production overseas by subsidiaries? Do the parent routinely consider alternative ways of capturing rents from these technologies in foreign markets?" (Emphasis added.)

Richard E. Caves, July 1974

7. "Research is much needed on whether the international diffusion of production technologies is materially hastened by exports, direct investment, licensing, or takeover bids, and whether there is any difference between the modes in accelerating the diffusion process. If the commercial channels make no difference, then the United States need delude itself no futher over its power to control the spread of technology. The United States could still attempt to sell technology in the most profitable form, but it should realize the weakness of its bargaining position. On the other hand, if the mode of transfer influences the speed of diffusion, the U.S. bargaining position is correspondingly strengthened." (Emphasis added.)

Gary C. Hufbauer, July 1974

8. "...(We) need a lot of in-depth case studies looking at competition abroad in order to determine what alternatives the U.S. firm has

(W)e have so few observations that we need a lot more studies of this nature....

Additional research is needed along the following lines in order to determine:

The economic effects of technological transfers

1. Conduct many in-depth case studies and industry analyses in order to define:

   a. the present practices of U.S. firms in selecting production processes for their foreign subsidiaries and licensees, adapting these processes to foreign conditions, transferring the technology, and managing an international network of manufacturing plants;

   b. the effect of foreign-owned activities on the decision to conduct research in the United States and abroad;

   c. the competition faced by U.S.-owned operations in individual product lines in specific markets, and how this competition is changing over time.

When such studies as these are completed, then additional modeling should be done.

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...Only after such studies will we have a clearer idea of what policy ought to be. We can then turn to studies of behavior to learn how better to influence firms as well as our own and foreign governments." (Emphasis added.)

Robert B. Stobaugh, July 1974

9. Ideally, one would like the following questions answered:

   1. What <u>military capabilities</u> of ours and the adversary's are important? (In what areas? Vis-a-vis what adversary? In what situations? How important, as a function of what the adversary(ies) possess?)

   2. What <u>technologies</u> lead to these military capabilities? (To what degree? With what possibilities for substituting other, perhaps nontechnological resources to obtain the same capabilities?)

   3. How do the <u>adversaries</u> stand in these technologies (sophistication, production capabilities)? How are they likely to progress? How do we stand and how are we likely to progress?

   4. If we "turn the dial" that allows more <u>trade</u> and <u>technology transfer</u> in these technologies, what is likely to happen (over what time frame) to different adversaries' levels of technology, given their (1) needs and priorities, (2) ability to absorb the technology, and (3) substitution possibilities?

   5. If the dial were turned, could capability-enhancing, militarily harmful applications be deterred by end-use safeguards? (What kinds of safeguards? Is the technology "extractable"?) (Emphasis in original.)

Robert E. Klitgaard, April 1974

10. "There have been several high-level studies looking for policy guidelines. None reached unanimous agreement. It is impossible, I think, to reconcile permanently such diverse views as are represented by the Departments of Commerce and Defense on one hand, and the Department of State on the other. However, I can give you my own personal viewpoint, which is shared by many on the Washington scene.

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...(Case-by-case) consideration of technology transfer is appropriate to avoid setting premature precedents with foreign nations. Case-by-case consideration will aid in the long run in building up a body of well-considered precedents to act as a guide for both industry and government agencies."

Edward E. David, Jr., January 1974

APPENDIX C

THE "CONVENTIONAL WISDOM"

according to
Edwin Mansfield

There are, I think, certain bits of conventional wisdom that can be passed on, which most people tend to believe, or at least this is what they tell one another.

One is that technology transfer is a people process. You hear this repeatedly, and it is probably right. For most purposes and most kinds of situations, if you want to transfer technology you have to transfer people. It is no good just shoving papers around or sending inanimate objects. What you have to transfer are the people. This is true both for vertical technology transfer and horizontal technology transfer. If you want to transfer information from development into production and do it properly, you send a development team from your development group, and they try to inject it into that framework.

Status is a factor, and all sorts of problems exist here, not only among countries, but the development people look down on the production people and the marketing people and so on. The customs of a country, of course, are a factor. All this is important in the transfer process.

Education, skills and management are very important, as are suppliers. . . . There is a necessary infrastructure that you must take into account, of suppliers, which may be quite different in other countries than in the United States. The education of the people is completely different. The management, the skills, all of these have to be taken into account. The technology cannot be looked at, independent of all of these other factors.

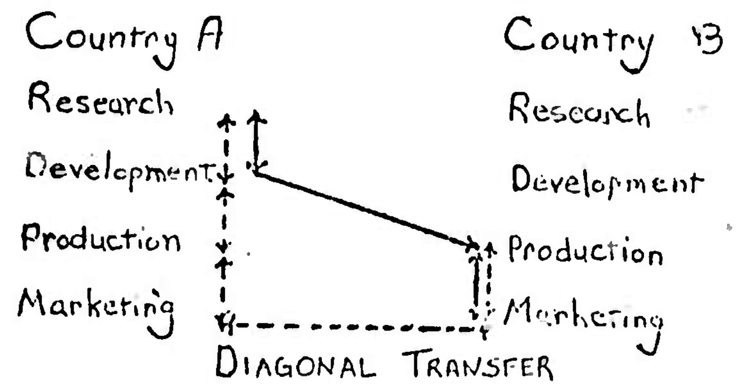
Adaptation, consequently, is often required of the product to meet the fact that there are small markets, the fact that there is government regulation of various kinds, the import restrictions, different skills, different factor proportions and so forth. Although many of the multinational firms are criticized for making too little in the way of an attempt to adapt things, they certainly do make some attempts to adapt. They have to, if the transfers are going to work.

There is another aspect of the transfer situation which it is important to note. R&D is becoming more international, more internationalized. . . .

What I mean by internationalization is that, for example in the IBM system 360, you had laboratories abroad--it used to be that you had a kind of local for local set-up. The lab in a particular country serviced that particular country. It made little adaptations. It was a service operation. In recent years, there has been more of a tendency to optimize over the entire globe, and to try to differentiate functions and coordinate all these laboratories.

For example, one of the machines in the 360 series, I believe, was developed in Germany. Another was developed in Britain. This makes for an enormous coordination job, but many companies feel internationalization is the route to take. . . .

(It) is often claimed that diagonal transfer is not possible. That is a shorthand expression. There is both a vertical transfer and a horizontal transfer. Many feel the diagonal is damn near impossible to do. Of course, all these aspects fit together, and this has relation to the split between development and production in the military. Here you have research and here development and here production and here marketing. All this is oversimplified, but say that you have one set at home, and the other abroad. Over time, the internationalization has gone this way. First you establish some marketing facilities abroad, then some production facilities, later some development facilities and now even a little research.



The idea is that you cannot cut corners. The costs are too high. So you have to go around the corner. Again, as I say, this is just conventional wisdom. No studies have been made to my knowledge of the costs, benefits, and efficiencies in such a situation.